motorcycle

Repair Manual 1972

By Bob Greene and the Editors of Motorcyclist Magazine

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FIND AIR LEAKS
LACE A WHEEL

CLUTCH AND
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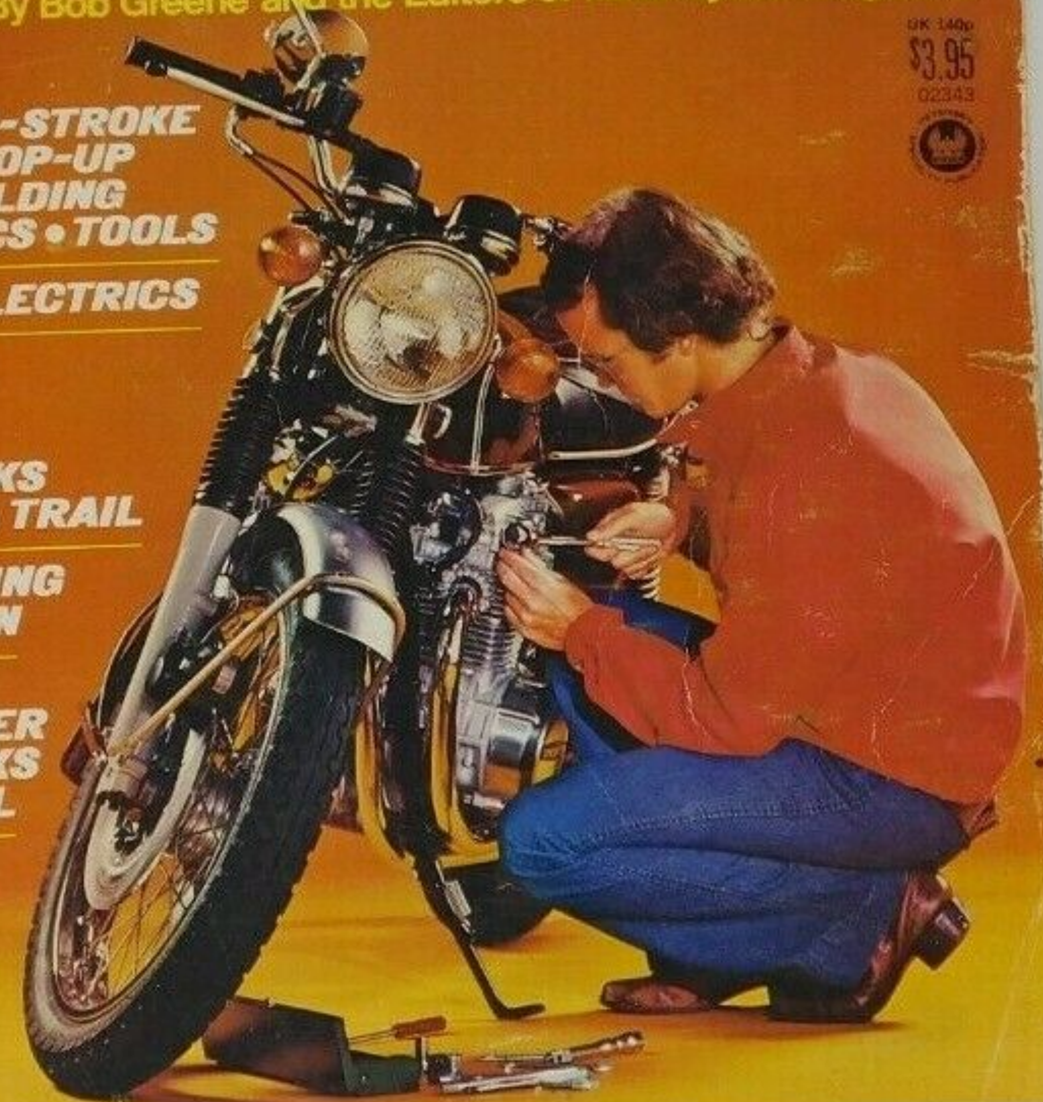

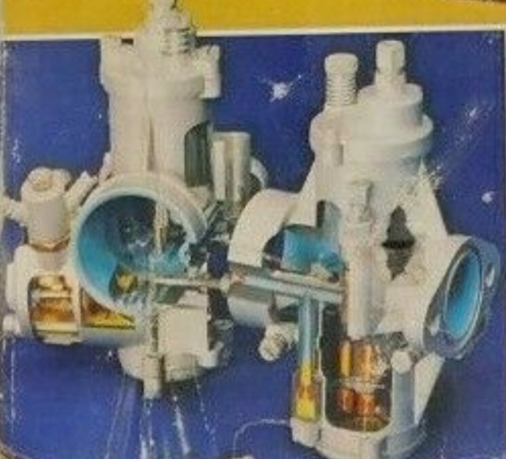

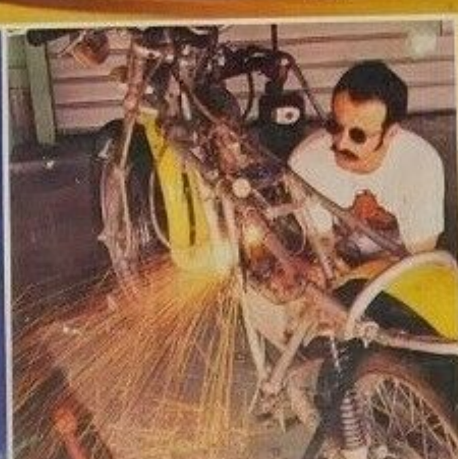

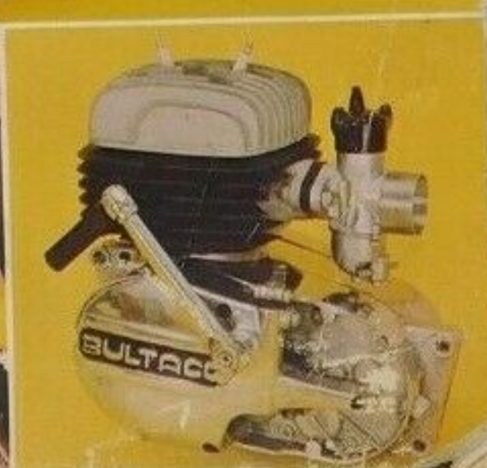

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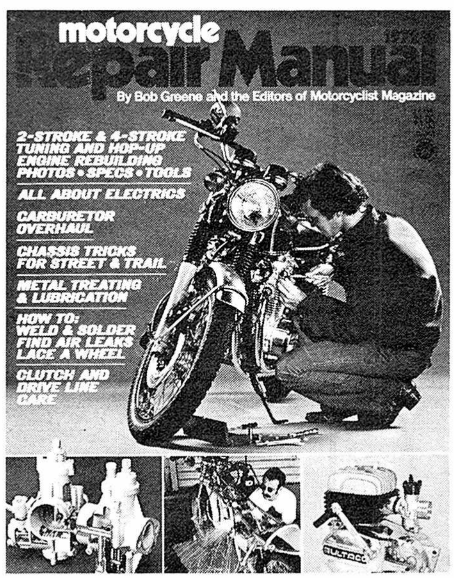

MOTORCYCLE REPAIR MANUAL

Edited by Dave Holeman/Art direction by Robert I. Young. Printed in U.S.A. by Crossroads Press, Effingham, Illinois.

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COVER

Motorcycle technology has far surpassed the dreams of yesterday's dealers and mechanics. Maintenance and repair have become more precise, but easier to accomplish. Our cover subjects include: MotorCyclist Magazine's art director, Paul Halesworth, performing minor maintenance on his Honda Four; a pair of unique IRZ carburetors from Ossa, cutaway to reveal their simplistic precision; chassis specialist Neil Fergus seen in the process of modifying a frame for serious competition and glistening proudly in the lower corner, Bultaco's latest two-stroke. Photography by PPC Photographic. Cover design by Robert I. Young, Art Director, General Book Division.

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INTRODUCTION

BY DAVE HOLEMAN

It's finally completed—the biggest motorcycle publication to come from the hallowed offices of Petersen Publishing Co. At least it will be finished when I complete these reverent words of wisdom to you. After these many months of eating, breathing and sleeping the innards of just about every motorcycle imaginable, these introductory words to you are the last to be entered in this monstrous catalog of repair, maintenance and tuning! At the outset of this enormous project I thought it would be impossible to fill almost 300 pages with technical information on motorcycles. Conversely, 292 pages can only scratch the surface when trying to set the tyro mechanic off to a good start in learning all there is to know about repair and maintenance.

We aren't trying to say that you will find all the answers between the covers of the MOTORCYCLE REPAIR MANUAL. But the contents of this book does cover the widest array of general motorcycle mechanics, for the beginner all the way up to the experienced professional, to ever be assembled in one publication. Like a recipe or formula, other elements are required to jell together all the data and information necessary to attack that problem-child in your garage. With hundreds of types and models of motorcycles in the hands of owners and riders like yourself, a factory service manual will be as important as a set of basic tools. Most important is your sincere desire to work with this book and the specs and data from the factory publication. We'll teach you if you want to learn.

Most of the editorial production of the Repair Manual was done during the fair weather spring and summer months of the year. When starting the huge carburetion section, a phone call to Yankee gave us a "more than we expected" reply from their Paul Dean. Shortly after requesting hard-to-find information on the unique double-needle IRZ carburetor we received not just data but the invaluable cutaway you see on the cover. Soon thereafter we received carburetors and more data from Bob Tryon (Triumph) on British Amals, accessory distributor Sudco came through with dozens of parts and pieces on Mikuni, George Croker of Harley-Davidson scrounged up some Bendix-Zenith and Tillotsen goodies and then came Lake, Posi-Fuel, Bing, Dellorto, Kendick and the rest. With the varied talents of former motorcycle dealer, Dan Cotterman the fantastic task of researching and writing was completed. Thanks to all of you who helped.

With the section on carburetors off and running, the task of finding competent and knowledgeable writers and photographers for the other 23 chapters commenced. Finding writers that specialize in one subject such as, wheels, oils and sprockets is easy compared to locating someone who's a jack-of-all-trades and master of none. Fortunately we were able to acquire the talents of workshop wizard Mike Capalite and his tool box of tricks. The largest and probably most important chapter of the book fell into his varied and capable hands on minor tune-up. From his decade-long mechanic experience and Huntington Beach, California service shop came invaluable filler for minor engine tuning material as well as trouble shooting. Mike's material will start you out with the basics needed to move on to more involved repair and research.

With one-third of the book in the works, the other ever so important chapters started taking shape. Former "Motorcyclist" Feature Editor Dale Boller tackled two of his favorite pet peeves, workshop tools and chain care. Dale is one of the most articulate mechanic-of-sorts one could know, but speaks with authority and knowledge. The lead chapter in the book is his tool article that contains the vital particulars of the equipment you'll need to start out with and what is needed to become mechanically

self-sufficient. Nowhere else will you find a more complete or thorough article on motorcycle chains than in Dale's chapter titled appropriately "The Final Link." Also added to the book is Dale's comprehensive article done originally in "Motorcyclist" on metal treating processes. Everything you need to know about X-ray, Zyglo, Magnaflux and more is there.

A very popular piece on most of the new adhesives, glues and sealants applicable for motorcycle use has been revived. The chapter on these helpers by Steve Greene has information every rider, mechanic or not, should know about. In a tube of sealant or a can of goo may rest the solution to hundreds of heretofore impossible fixing and mending chores. It's good, informative reading for all.

Lubrication authority, Pepe Estrada tells all in his lengthy but revealing section on oils and lubricants. Many days of research went into locating the right people in the petroleum industry so Pepe could tell it like it is. An aggressive young writer/photographer named Jim Lewis magically filled the void for us in the electrics department. Electrical theory and its relationship to practical application is doubtlessly the most difficult subject to deliver to the beginning motorcyclist. Jim has approached the subject in a novel, yet effective manner. He talks about British, Japanese and other popular systems, how they work along with the basics of electrical troubleshooting.

With most of the basics of motorcycle repair covered, delving into more involved subject matter for the more experienced rider was next. Heading up this more advanced area is a chapter on preventive maintenance where a lot of loose ends that hang between experience and practical knowledge were picked up. A rookie free lancer named Bill Ocheltree came up with a mound of invaluable maintenance tips that are worth their weight in gold. Bill, a former aerospace engineer, has far more to contribute as I'll point out later. Wheels and tires and how to lace up a new rim and hub are all covered in an excellent combination technical and how-to article by Robert Schleicher. The practical application methods of welding, soldering and riveting are covered in depth by our friend Dale Boller. These pieces are invaluable articles for the budding mechanic and should be considered "must" reading. Of course, lest I forget, the chapter on pressure checking two-strokes is by this writer. You two-stroke owners will find this article a real money saver for finding those potential disastrous air leaks that can plague any and all ring dings.

Once past the tuning and maintenance chapters, the heavier nutsy-boltsy sections were next on the list of musts for the more involved owner. This is where the absolute need for those factory service manuals and specifications become a must for the garage. Two-stroke engine rebuilding would have been all but impossible to produce without the invaluable aid of Yamaha and their fantastic service department. As you will doubtlessly notice, the lion's share of the photos represent this two-stroke giant and would have left the article full of holes were it not for their contribution. As it turned out, their photography was used extensively throughout other sections of the book pertaining to various other subject matter. It seems that the rest of our time was spent with Kawasaki's Windy Briggs and Skip Newell, without whose help completion of quite a few of the articles would have been impossible.

Many visits were made to motorcycling's "numero uno," Honda. Needless to say one couldn't contemplate attacking a project the size and scope of the REPAIR MANUAL without the assistance of this two-wheeled big-timer. Fortunately, we had some inside help from one of our contributors, Joe McFadden, who is one of Honda's technical editors. Finding it right at the source, so to say, enabled Joe to produce some superb copy on four-stroke engine overhaul. Once over the hump of engine disassembly and assembly, all the hot scoop on motorcycle clutches and gearboxes came from the voice of experience, Dan Cotterman.

But not everyone is interested in repair and maintenance. Some like to just tinker while others want to know everything possible about why it works, how to get more from your machine, and theory. We have just what the doctor ordered. The mystery and design of motorcycle suspension and springs are covered in an unusual but effective manner by "Motorcyclist" Editor Bob Greene and yours truly. To complement the informative section on suspension a rare piece on chassis design and geometry, the whys and hows, by this writer fulfill this dark area of motorcycle construction.

For you hotshoes, we have what I must consider the best features on motorcycle hop-up ever done. Our consulting engineer Bill Ocheltree came through with a most unusual editorial piece as an introduction to hop-up called "More Horsepower." It isn't a light article for the average reader, but it presents the aspects of squeezing more power out of any said engine in a perspective not thought of by the average tuner. Superb reading. "Motorcyclist" Technical Editor Tony Murphy came to the rescue with his usual excellent editorial on two-stroke hop-up. Combining his professional racing background with technical know-how ranging from Yamaha Racing Manager to home building race machinery, Tony puts it all in print and doesn't beat around the bush. Next, we put our engineering consultant, Ocheltree, at it again. This time it's four-stroke hop-up chapter told in a manner I doubt you've ever seen before. Not too nutsy-boltsy, but technically informative as only an engineer could tell it.

And just to show that we have something for everyone, there's an in-depth chapter on motorcycle engine tuning by oscilloscope. Honda technical ace Joe McFadden managed to crank this out while working on the oscilloscope kit soon to be seen at your local dealer. Not reading for all motorcyclists, this "Tuning by TV" chapter should find a home in every mechanics tool box.

To finalize the REPAIR MANUAL, there is a concluding chapter on specifications and formulas that every motorcyclist will need and use at one time. This is timeless data that will always be valuable. Then on the last page is a list of motorcycles, their distributors and where to buy factory service publications and data.

There isn't enough space or time to thank all those involved in assembling the mountain of material required to complete this book. One infamous staffer that does deserve special thanks is Photo Editor, Eric Rickman who I had running in and out of every shop, manufacturer and distributor within range for those missing and last-minute pictures. Thanks Rick. If we haven't told you enough (or possibly given you too much) let us know so that the next MOTORCYCLE REPAIR MANUAL will again be better than the last. And as Bill Ocheltree would say, "keep your spokes tight."

TOOL UP

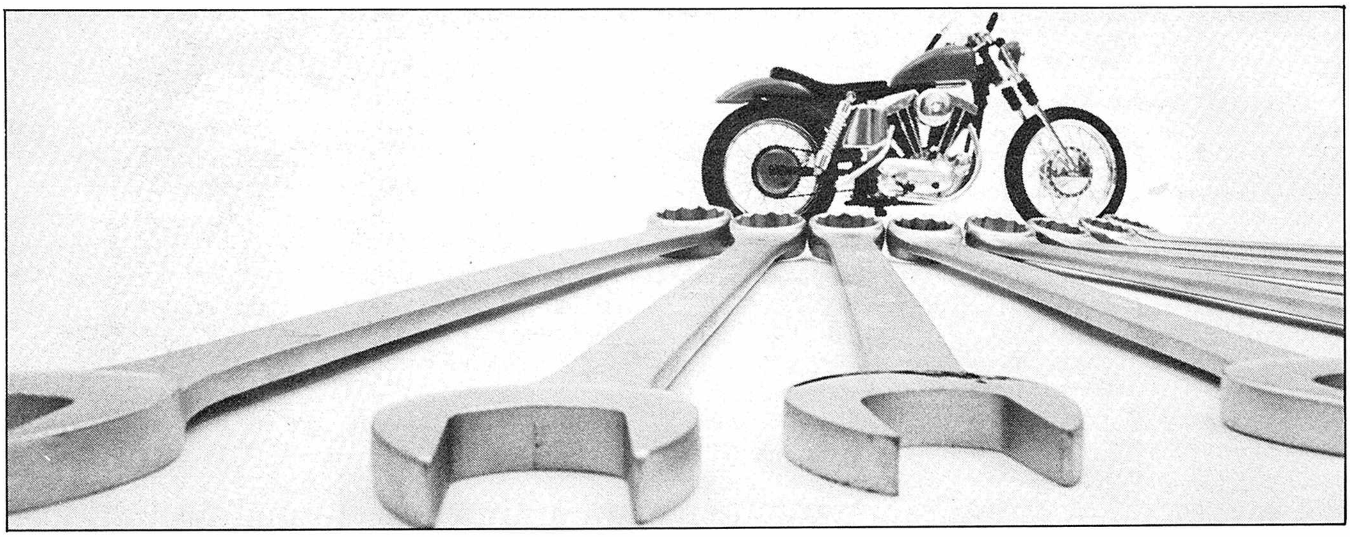
Before you can even think of working on your bike, there are a few things you'll need. But remember, there's no such thing as a "good" cheap tool

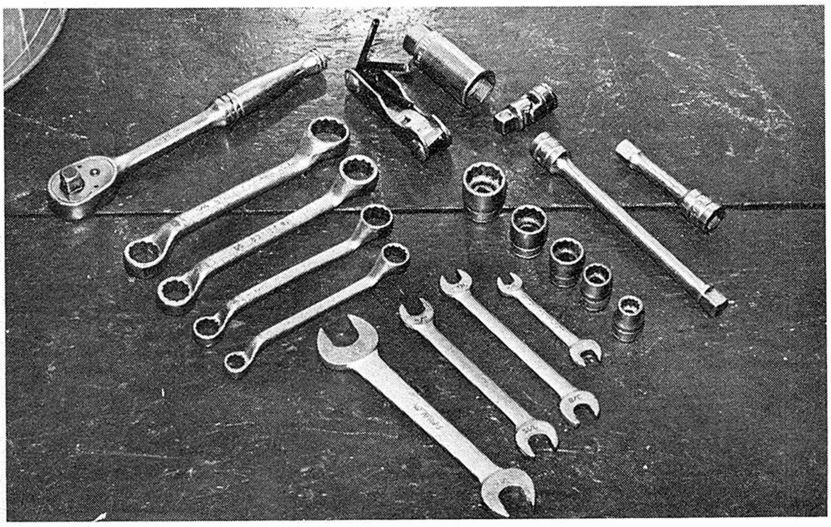
BY DALE BOLLER

There's an old quotation by that famous scribe, "Anonymous" which says, "A good workman is known by his tools." How many times have you lost faith in a mechanic upon discovering his workshop was some cluttered corner in a dark garage with bent and battered tools strewn about in greasy disarray? His work is probably just as makeshift and inferior as his workshop. Indeed, miracle machines often come out of the most unsuspecting locations, but in general, a clean and well-equipped shop produces the best motorcycle repair. A professional mechanic will accumulate tools worth as much as two or three brand new 750's and the home mechanic will require about $300.00 in tools to do a complete tune-up, minor repairs and routine maintenance. Therefore it's important to know how to purchase, use and maintain tools and which ones to buy in the first place. This article will discuss these subjects in terms of the home mechanic.

Another famous scribe, Carlyle, said, "The tools to him that can handle them." The most important tool in a rider's possession is his mechanical ability. Anyone without some measure of proven technical skill, or a budding potential eager to be developed with proper guidance, should leave repairs to the pros. There's too much at stake for a natural bungler to start aligning wheels or just touching a nut with a wrench. A person is only as safe as his own riding, and the bike, and an amateur wrench unknowledgeable or incompetent to the point of endangering the safety of a bike must steer clear of mechanics. Save your money in some other area if you don't know what you're doing.

There are about as many ways to go with tools and a home workshop as there are tools in the Snap-On catalog, and that's a bunch. Most mechanics agree that a complete shop grows slowly over the years. A beginner will have and need only a few tools commensurate with his mechanical ability and complexity of his motorcycle. His shop will grow in pro-





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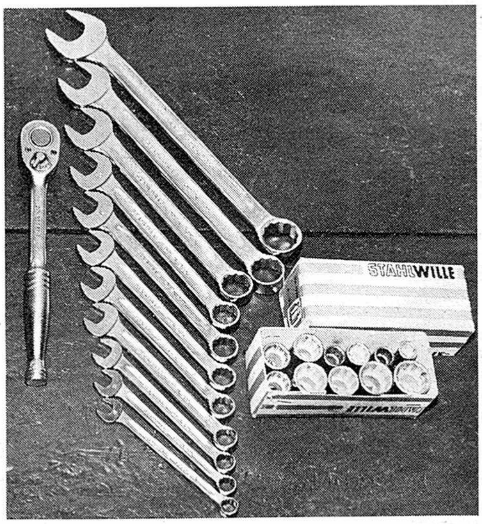

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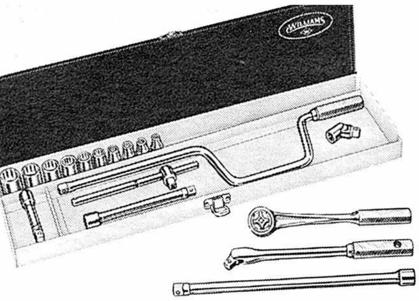

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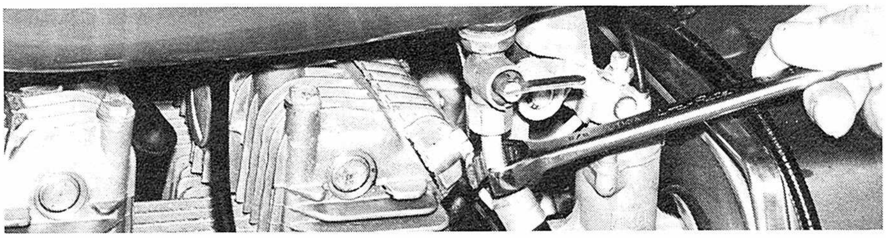

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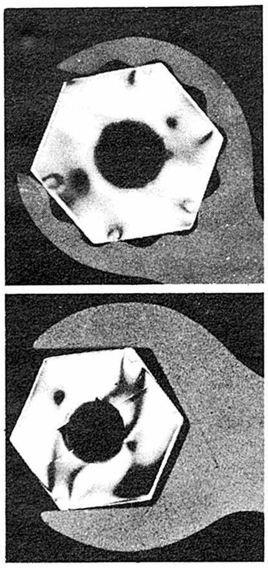

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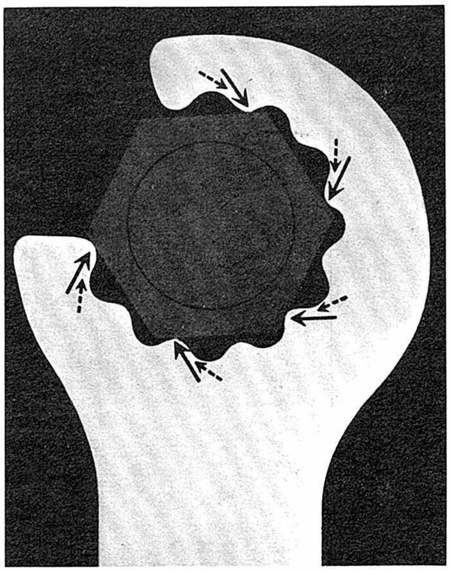

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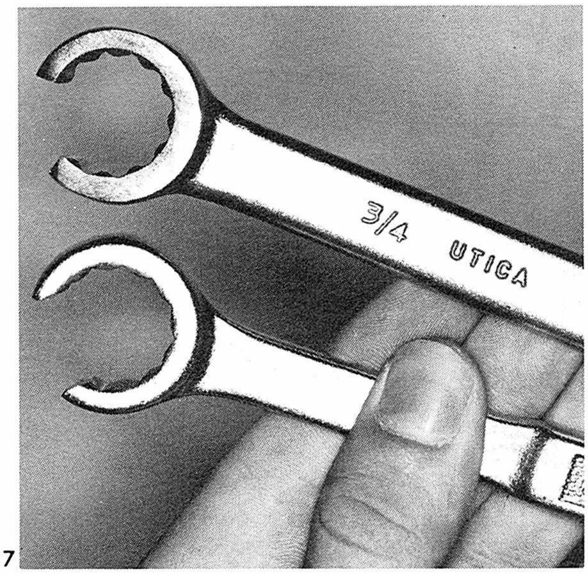

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1. Most home workshops already have a small collection of American inch tools. Some interchange with metric.

2. Most all imported motorcycles today use metric-sized hardware. An investment in good metric open/box combo wrenches and sockets saves working time and damage to hardware.

3. Top quality socket sets aren't cheap, but will last for many years. Start off with basic set, then expand.

4. Handy LocRite wrench fits over metal gas line, then onto soft fuel nut for damage-free tightening.

5. Infra-red X-ray shows minimal stress with LocRite tool while conventional open end wrench exerts center directed force which distorts nut head.

6. Lobes exert a true twisting force tangent to the bolt's center as opposed to center-directed crushing force exerted by conventional wrench.

7. Lobular surfaces of LocRite wrench on right differ only subtly from flat surfaces of standard design, left.

8. Convincing demonstration measures torque at which various wrenches round off the corners of hex head bolt or nut at 22 foot pounds.

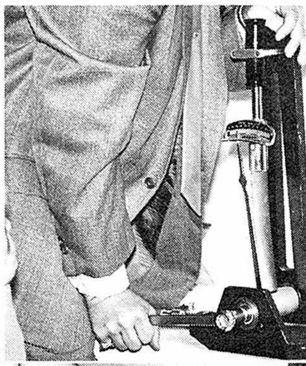
9. Standard open end wrench slipped over hex corners at 22. ft, lbs. The damage incurred is enough to render the nut or bolt useless to torque down to proper specs again.

10. LocRite wrench torqued down the same damaged hex to 60 foot pounds torque without slipping or causing further damage to the corners.

portion to his interest in motorcycle repair and his budget.

Inexpensive tools versus quality tools: Starting with cheap tools will build a large working set more quickly, but once you've tried a slick-fitting Williams socket or drooled over a Proto catalog, you'll end up replacing many of your original purchases. Personal pride in owning what you know are quality tools is also another factor in buying the best. Pick up a quality wrench and it's like examining a fine piece of sculpture, perfect in every detail, almost too good to use and certainly conducive to proper care and handling. If the aesthetics of quality tools don't convince you of their worth, the short life of cheap ones and damage they do to nuts and bolts certainly will. Good tools are something you buy once, for with care, they will last a lifetime. Do it in the beginning and you will save money in the end. Just as the motorcyclist starts with a 90cc trail bike and is soon shopping for a Triumph, the mechanic will eventually want the correct tool for every job, and preferably the best tool.

Admittedly, it takes experience to know what you're doing, so how can you gain experience? Here are five ways: First, have confidence in yourself—you can do it. Second, read up on motorcycle and engine theory to build a strong foundation. There are



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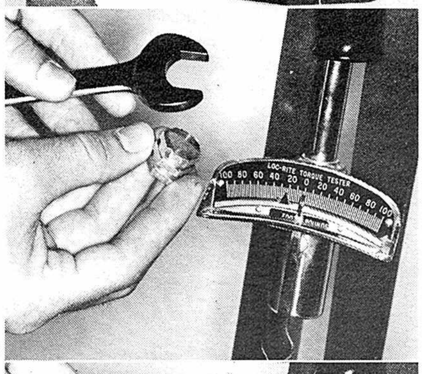

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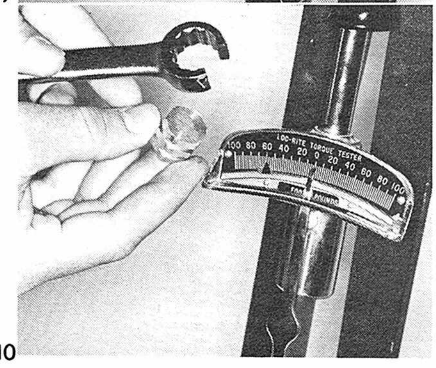

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TOOL UP

about half a dozen good books on the subject available through Bagnall Publishing Company and Clymer Publications. Your closest dealer may be able to suggest a few titles also. Read the technical pieces which appear in the monthly magazines since they are more current than books and may often deal with a specific problem on a bike you are intending to repair. Third, consider one of the many courses presently offered in motorcycle mechanics by trade schools. They are usually a minimum of one semester in length, but difficult to enroll in because of a waiting list and sometimes costly in tuition. But other than full-time apprenticeship next to a factory-trained mechanic, the schools are the best way to go. Fourth, buy the factory service manual ($5.00 to $10.00 from your dealer) for the bike you will repair and watch for the distributor's service bulletins which should be posted in your dealer's shop; if not, ask him to see them and transfer any specifications or procedure changes in the bulletins to your service manual. Fifth, talk to people. Discuss your bike and its idiosyncracies with other owners of the same model at every chance you have. Someone who recounts cam chain trouble on his bike at 6000 miles has just tipped you off to adjust yours carefully at 4500 miles, well in advance of any possible trouble. Talk to mechanics at the dealership. Talk to race tuners who build competition bikes out of your model. But if these sources can't tell you *why* your problem occurred, beware of *how* they said to fix it. A good mechanic knows both; otherwise he's just a grease monkey.

Confidence, theoretical background, service manuals and other people are all part of your tools. But now down to the basic hardware—wrenches, pliers, sockets and the like.

When you're faced with a choice between similar, but different tools—such as six-point box wrenches versus 12-point box wrenches or a "soft" rating on a plastic hammer tip versus a "medium hard" rating—ask a seasoned mechanic the differences and which is best for motorcycle work. He'll tell you to buy the 12-point wrench because it requires less throw to take a new bite and thus can be used to more advantage in the many limited access areas on a bike. Then he'll explain that hammers are available with removable tips and you need one soft enough to push in with your thumb nail and one irresistable completely to thumb-nail pressure. He'll tell you which screw extractors work and that pre-set torque wrenches with an audible signal are easier to use than the deflecting-beam type.

Common sense, your professional friend and the accompanying "Basic Workshop Tools" chart will help you decide what tools to buy. Common sense, professional advice and the following suggestions will help you to buy them for the least amount of money. Top-rate tools are extremely expensive and are rarely discounted to individuals. However, industries buying in volume, wholesalers, distributors and retailers obtain their supplies considerably below list price and their employees are often allowed to purchase tools at company cost. Make friends with someone who has such a privilege and buy your tools through him. Another way to save up to 25 percent is to find a wholesaler willing to sell to you direct; it's not illegal if you can justify professional

BASIC WORKSHOP TOOLS

(Prices are an average between equivalent listings in the Sears and Proto catalogs)

Allen wrench set	$ 1.00
C-clamp, 6-inch	5.00
Calipers, dial-type	30.00
Center punch	1.00
Chain breaker	4.00
Circuit tracer	5.00
Drill, electric (3/8-inch)	25.00
Drill bits, set of 10	12.00
Feeler gauge	5.00
Files, triangular, flat, rattail	10.00
Hacksaw, adjustable	4.00
Hammers:	
Ball-peen	5.00
Soft tip	4.00
Knife	4.00
Paint brush (for cleaning)	1.00
Pans (for oil draining)	3.00
Pencil magnet	1.00
Pliers:	
Needle nose	4.00
Wire cutter	4.50
Regular	2.75
Channellock	4.00
Vise, grip-type	4.00
Circlip remover	3.00
Propane torch	10.00
Puller, universal-type	10.00
Rule, metal	1.00
Screwdrivers:	
4-piece blade set	8.00
4-piece Phillips set	8.00
Sockets (3/8), 20-piece set	30.00
Soldering iron or gun	10.00
Strap wrench	3.50
Tin snips, right- and left-hand	5.00
Wrenches	
Adjustable:	
6-inch	2.75
10-inch	3.75
12-inch	6.00
Combination, 8-piece set	20.00
Impact	12.00
Torque	25.00
Extras: Loctite, grease, oil can, etc.	10.00
TOTAL, approx.	**$300.00**

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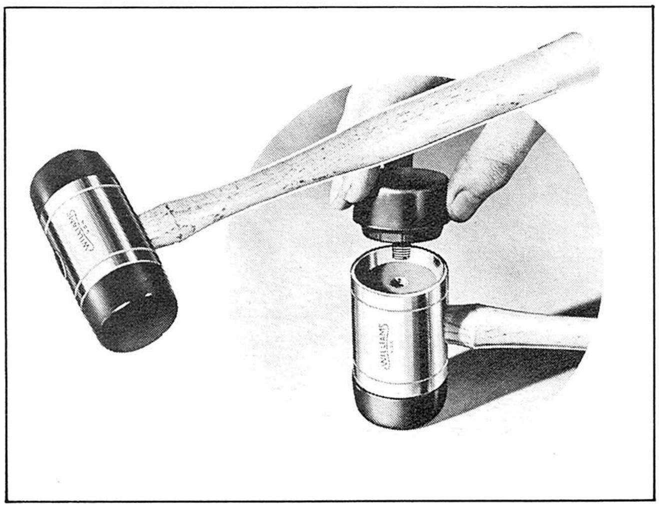

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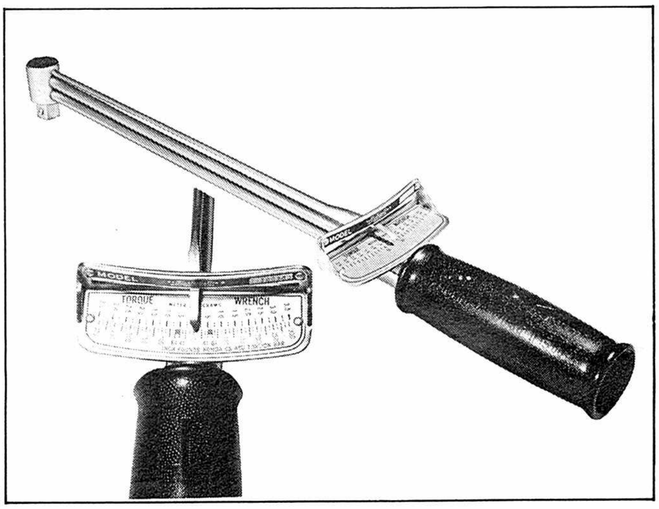

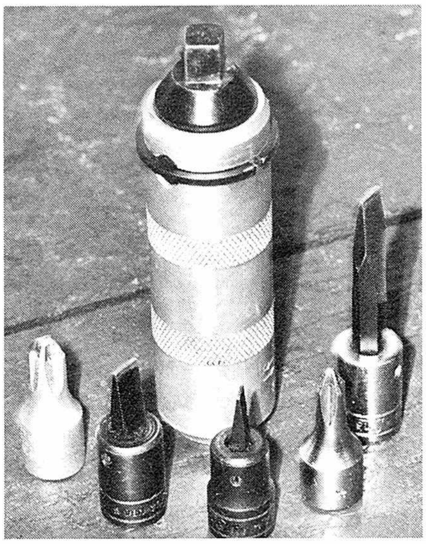
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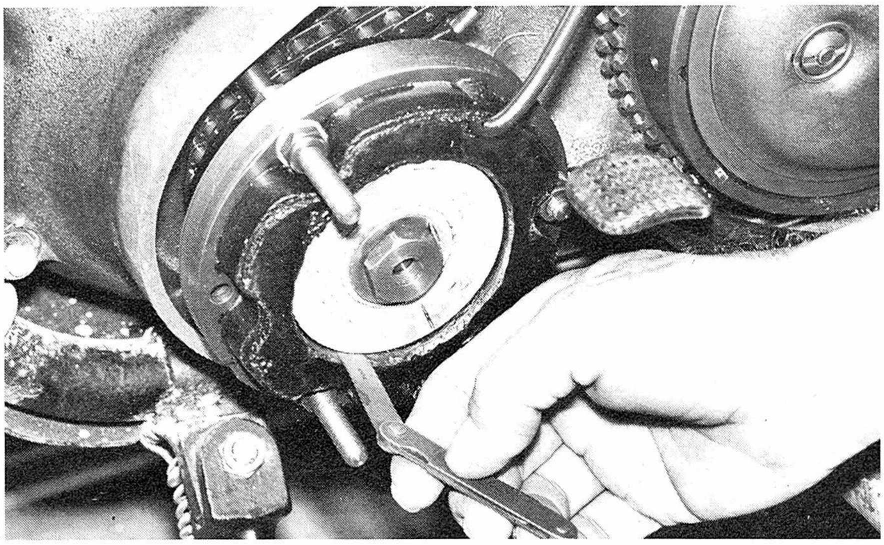
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use of your tools in almost any remote way, such as working on a race bike which competes for money or working as a mechanic for pay. You can save about 10 percent by buying tools finished in industrial black; they are no different from the satin-chromed version in metal, machining or broaching. Then there are the occasional sales on name brands. Wait for them. In some brands you save money by purchasing a set instead of individual tools. But beware of enormous sets that include many specialized items you'll never use. Sets also preclude mixing brands which often occurs when you prefer one maker's sockets but not his pliers, or go to a third manufacturer for screwdrivers simply because you like their feel. Brand loyalty toward tools among mechanics is often quite strong, but regardless of brand, most everyone succumbs to a bargain price on a top-line item.

Choosing the right tool is like choosing the right wife. Both have to give you good results for the rest of your life. Selecting the tool is a lot easier than finding the chick. Simply round up a few catalogs from some of the following major manufacturers: Blackhawk, Bonney, Craftsman, Crescent, Indestro, Mac, OTC, Proto, S-K Wayne, Snap-On, Utica and Williams.

There are others but these manufacturers are the biggies and their wares are superior. Thumb through the catalogs to determine what is available and at what cost. You'll have to request a separate price list since cost rarely accompanies catalog descriptions. An evening with a catalog is fascinating and informative and gives you an idea of how much there is to learn about the subject. Did you know there are special pliers which automatically twist lock wire in seconds? That hacksaw blades come in 18, 24 or 32 teeth per inch? That Utica makes a tangental-drive Loc-Rite wrench which will unscrew bolts hopelessly buggered or rounded-off by conventional wrenches? Or that Williams offers a torque multiplier capable of displacing 2000 foot-pounds which weighs 102 pounds and sells for $1532.50? Becoming aware of both the basics and exotica is the first (and interesting) step.

Next, go directly to the retail outlets so you can see and handle the merchandise. Wander through your local Sears tool department for a variety of mechanics tools. Look for the word "Forged" or "Drop Forged" stamped on the tool; every maker who uses this superior process will so indicate. Check on the guarantee. It should be cut and dried: If a tool breaks in normal use, it's replaced

1. Soft tips of plastic, leather or lead are a real necessity around the garage. Some hammers have replacement tips as shown. This permits a soft metal on one side, plastic on other.

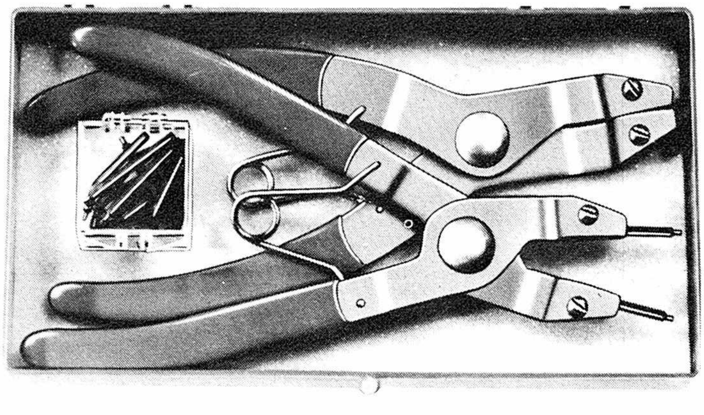
2. An absolute necessity is a torque wrench. This Sturtevant wrench is calibrated in meter-grams and inch-pounds. Others are available that give both foot and inch pounds.

3. You won't get to first base working on an engine without an impact driver for slotted and Phillips screws. Keep this in your tool box.

4. Feeler gauges are the only way some measurements can be taken. They are flat steel or wire. Be sure the ones you get are stainless steel.

5. Trying to get engines and wheels apart is virtually impossible without snap ring pliers. They come in two types, open-out and close-in, with tips.

6. There's just no replacement for a ring compresser when needed.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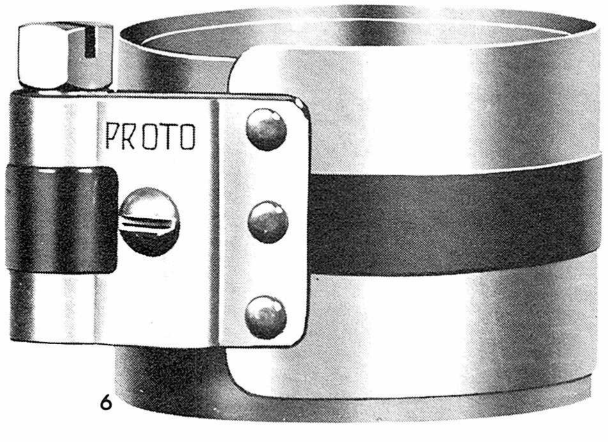

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free of charge. Ask if the tool has a "military description" or "military order number." If so that means the Army buys it and it's up to rigid government specs. Bring a bolt along on your browsing session and check the fit of various wrenches; if your selection has noticeably more play than a Williams, Snap-On or Proto wrench, don't buy it. Examine the mesh of pliers, the thickness and uniformity of screwdriver blades and the amount of slop in the moving jaw of adjustable wrenches. You'll soon know how much of what certain deficiency is intolerable.

SPECIAL TOOLS

Although the special factory tools available through dealers for specific jobs on your bike such as removing fork seal covers or pulling cam gears are of main concern to professionals, the shade-tree mechanic should be aware of their existence. The service manual generally pictures all the special tools available for that particular model. Sometimes a couple of pullers, a flywheel holder and an odd-shaped wrench comprise the whole assortment and cost is around $20.00, but often carb synchro gauges and electronic timing equipment can raise the price of a factory tool set up to $100.00 as is the case with Honda Fours. It's usually wise to buy only the items you need for home workshop jobs—why pay for a main bearing removal tool when you'll never use it?

One piece of equipment which all mechanics must have is a torque wrench and its importance bears special mention here. There is an engineering phrase that says, "An overtorqued bolt is already half broken." If torque was no big thing, there wouldn't be long lists of twisting limits in service manuals or 50 different kinds of torque wrenches on the market. For most all motorcycle work, a torque wrench that reads in "inch pounds" is best. All bolts stretch slightly when tightened. Torque is the force required on the bolt to produce the desired degree of stretch to mate surfaces evenly with just the right amount of tension to withstand heat expansion, protect the gasket and prevent warping from overtightening.

Riders plagued with engine oil leaks (most of us) can reduce seeping by 70 to 80 percent by fitting new gaskets with weather stripping and torquing bolts to factory specifications. A wrench capable of this job will cost about $25.00. Torque is measured on the basis of a fundamental law of physics regarding leverage: Force times distance equals torque (twisting force) around a pivot point (bolt head). If one pound of force is exerted around the bolt center at one foot from that center, the torque is one foot-pound. If the distance is measured in inches, then the torque is read as 12 inch-pounds.

The easiest place to shop for tools is at an automotive parts jobber or major hardware store. Some brands, including one of the best available, Snap-On, are not sold in retail stores, but only by factory-franchised agents who sell out of trucks. You can locate these agents in the phone book and they will come directly to your house whether you want one pair of pliers or a complete set. Don't ignore the mail order houses either. Note well that the catalog price is usually a bit less than the over-the-counter cost.

Many people weigh the price of a repair job by the dealer with the cost of the tool necessary to do it them-

1. In time you can accrue a supply of sundry tools for the special tasks of your particular machine. Don't lend these to your friends.

2. Plan on having a gear puller of some type in your supply. They come in two or three prong varieties. Keep away from cheap imported pullers.

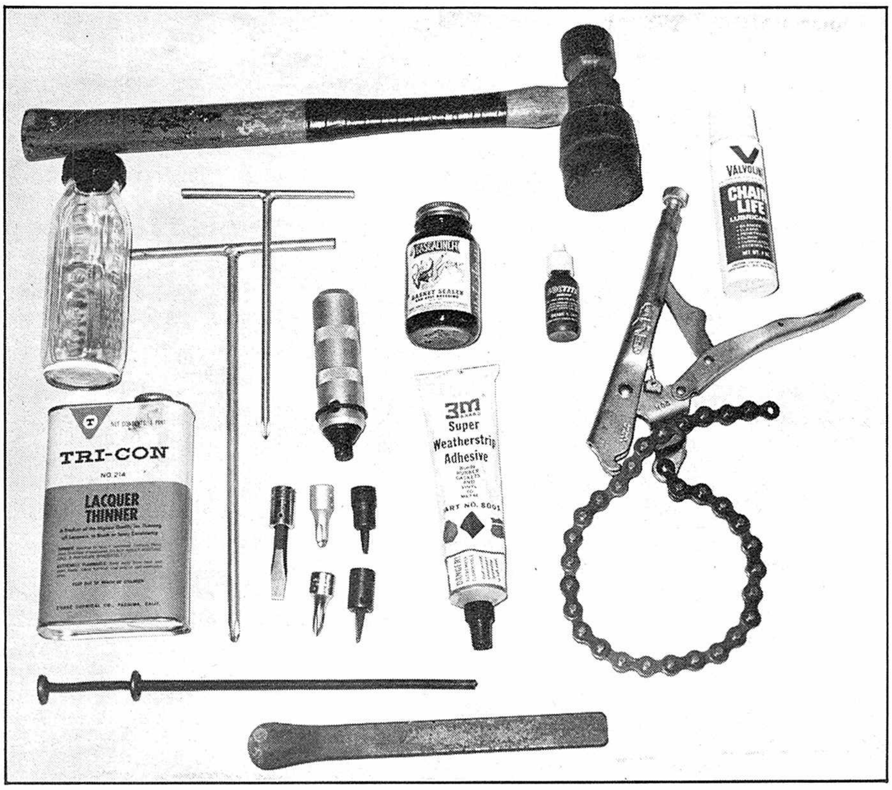
3. Many of the magneto and alternator rotors are very difficult to remove, particularly if they've been LocTited. A shock puller (shown) can be ordered from your dealer or special made.

4. Speciality tools include a mixed set of small files, deburring tool and jewelers magnifying glass. These are often found during special sales.

5. Bolt head markings indicate SAE tensile strength ratings. Always use grade five or better on your bike.

6. If you progress up to having compressed air a high speed impact driver will save hours of wrench turning. There are also electric models.

7. One of the musts is a set of good grade high speed drill bits. A practiced mechanic will learn how to sharpen drills on a bench grinder.



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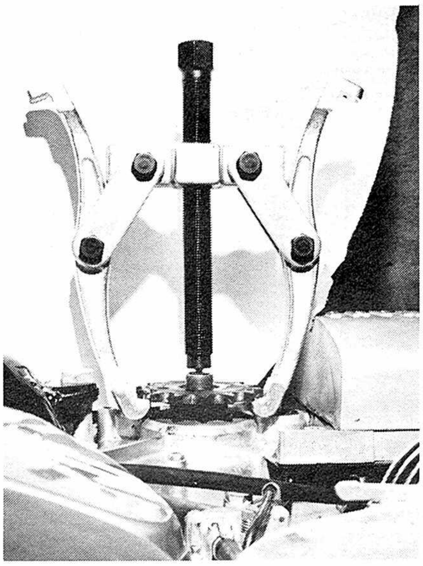

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selves. If the costs are at all close, you are better off doing it yourself and ending up with the tool. In a few years you'll have a self-contained shop which prevents the frustration of being halfway through an engine teardown only to be stopped for lack of a certain tool. Once your shop is self contained, new tools will be luxury additions to make things faster or easier. Most mechanics never stop buying tools. Tools are in the same category as vehicles for hauling bikes—expenditures for them can exceed the value of the motorcycle.

TOOL SAFETY

Be careful when using your tools. Tool safety is almost an insulting subject until you are hurt or become aware of the following statistics: There is an industrial accident every 15 seconds in America today; someone is killed on the job every 39 minutes. Disabling injuries totaled just under 2,000,000 in 1968 with unsafe use of hand tools contributing to more than six percent of all industrial injuries. The Pennsylvania Department of Labor and Industry reports that using defective tools or equipment and using them in an improper manner are the principal unsafe acts contributing to 54.7 percent of injury cases analyzed. The assumption that common sense will dictate proper use of hand tools is not borne out by the accident records. Here are some rules: Don't use a pipe for extending a wrench handle, use a bigger wrench. Always pull a wrench instead of pushing it so your hand won't be smashed by ramming into the work if the wrench slips. Don't use screwdrivers on objects held in your hand. Carve and file in strokes away from your body. Don't substitute tools, such as using a pliers for a wrench job. Before doing any extensive work around the shop area, remove rings and wristwatches; they catch on things and if bumped on a battery terminal, can burn. Beware of battery acid which eats clothing. Fumes from a battery are explosive so keep anything capable of sparking away from the battery, including a hot light bulb. While charging, a battery

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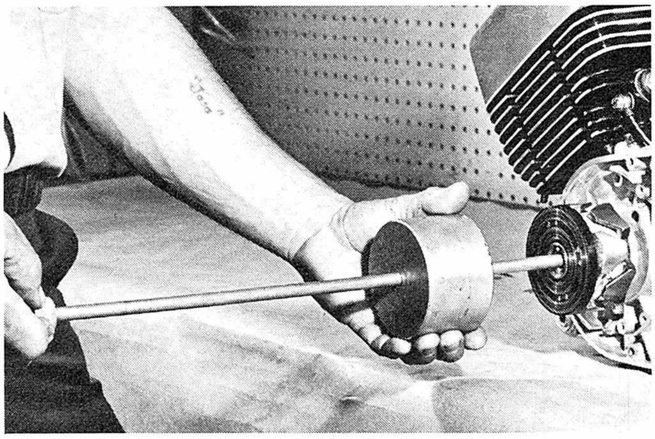

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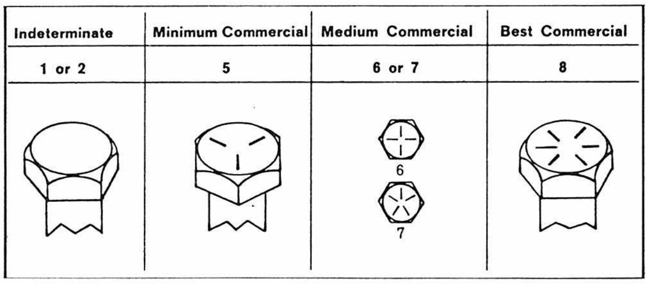

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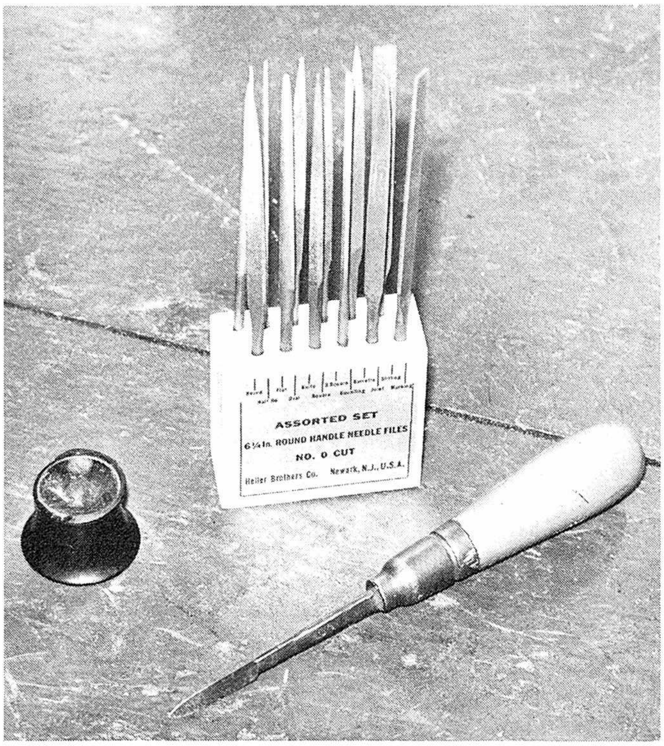

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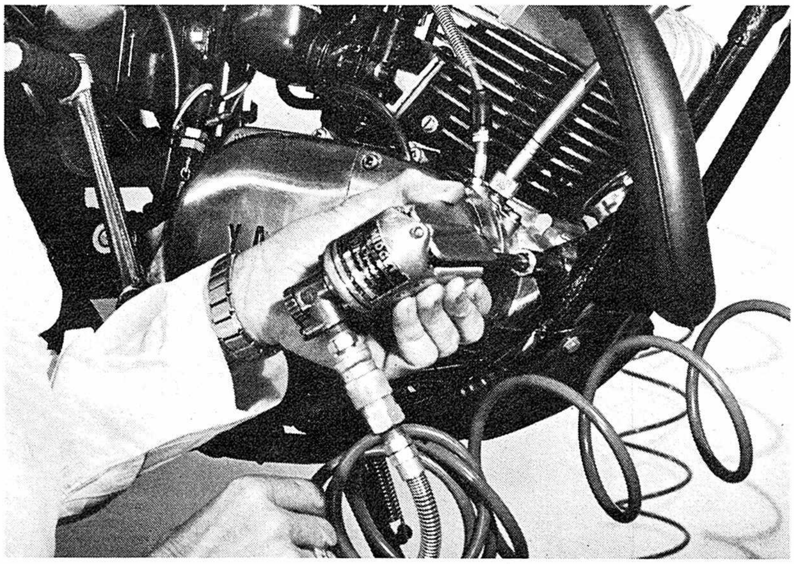

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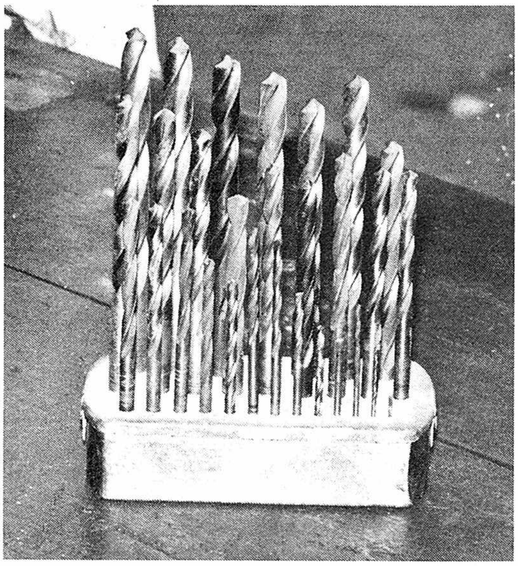

expels hydrogen, another explosive gas which must be isolated or vented away from spark or flame. If you must store oily rags between washings, keep them in a closed metal container to prevent spread of flames if fire starts by spontaneous combustion. Just in case, keep your fire extinguisher easily accessible. Be sure the plastic insulation on pliers handles is intact before tackling the ignition system. If your power tools come with a ground wire, use it. Always wear safety glasses when there is any chance of eye damage, especially around grinders. It's pretty hard to ride and point a white cane at the same time. Finally, realize that every worn or mutilated hand tool is a potential accident, and so is every distraction while you're working, so keep the dog, the kids and your girl friend at a safe distance. Using tools safely is quite simple really. Employ logic, set them down carefully—don't drop them with a clang—don't loan them out, identify them with your initials and keep your hands clean and dry when using them.

CLOSE AT HAND

Storing tools is not as easy as it sounds. They are among the most commonly stolen items in existence, along with motorcycles, Corvettes and car stereos, so a chest with adequate theft prevention is important. Furthermore, tools exposed to the air will suffer from corrosion and rust speckling in just a few months, so a relatively airtight storage method is important. Tools will maintain their lustre inside a good chest. Elaborate wall mounting inside a dealer's shop is fine, but garage air will take its toll soon unless tools are sprayed with a light oil—but this coating often inhibits their use by staying slippery. A chest can be just as convenient if it has built-in casters or you mount it on a home-made rolling platform to enable easy placement close to the work. Here are some toolbox tips: Choose a chest large enough to contain your working set but not too heavy for two people to lift into your truck. Make sure the drawers will pull all the way out; some only have ⅔ travel which impedes access to the rear area. Make sure the vertical reinforcing sections in the middle of the drawer don't divide it in such a way that precludes storage of longer wrenches, drill motors or other large and bulky items. Oil the runners carefully with 90 weight gearbox oil—it won't push out or thin enough in summer heat to drip. Finally, hit up the seller for free lining material—either vinyl, plastic, rubber or cork.

What if you live in an apartment and have no place to work on your bike? Here's where a good set of tools comes in handy to negotiate with a homeowner for space in return for use of your tools. Loaning tools is usually strictly taboo, but it will be easy to locate a working and storage area with a good set of tools to bargain with. Some groups combine forces and finances to really go whole hog on a workshop. Several wallets can afford a roller chest, welding equipment and even an air compressor in addition to hand tools. Groups can be club members, owners of the same brand motorcycle, friends, relatives, even car people. An important rule in group buying is to establish beforehand what happens to a drop-out's share. Usually his portion stays with the group, members buying him out.

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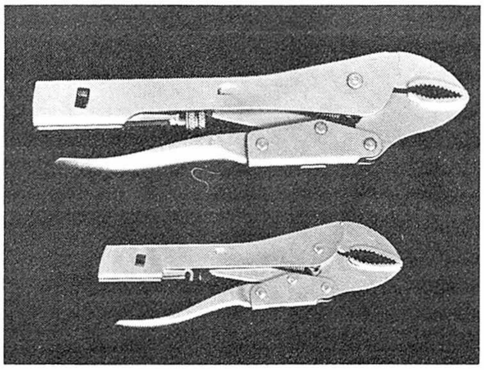

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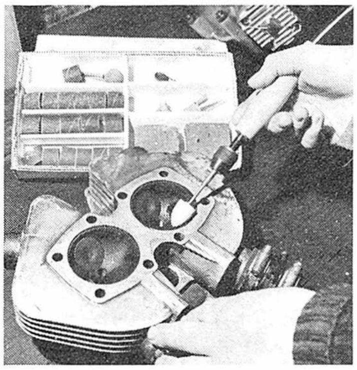

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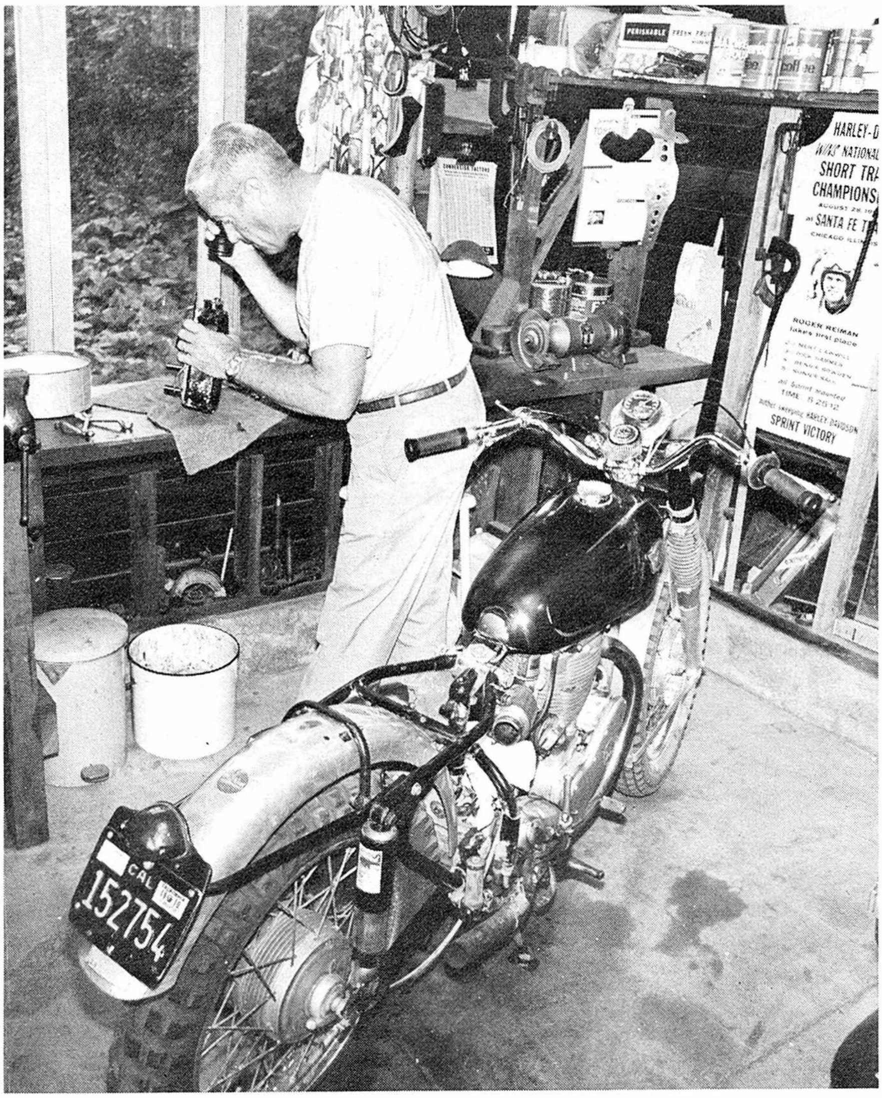

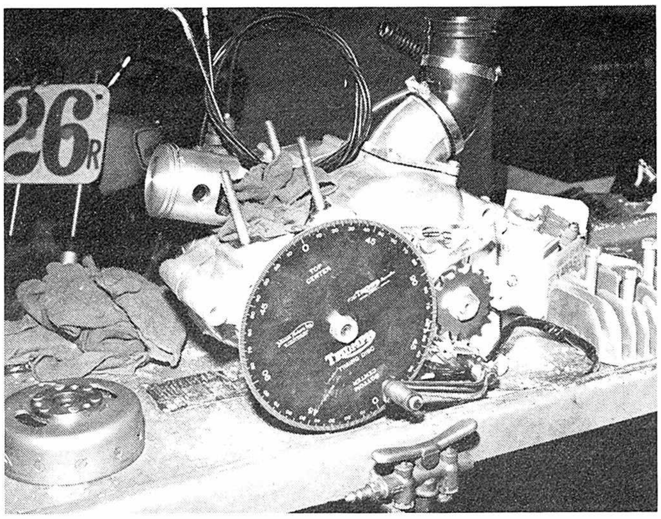

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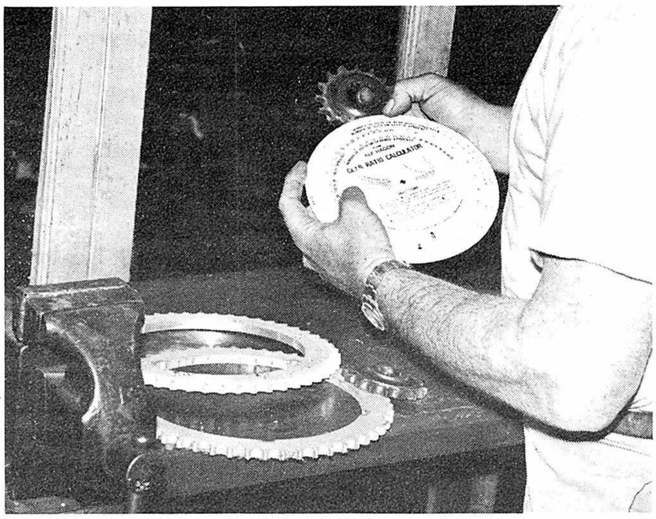

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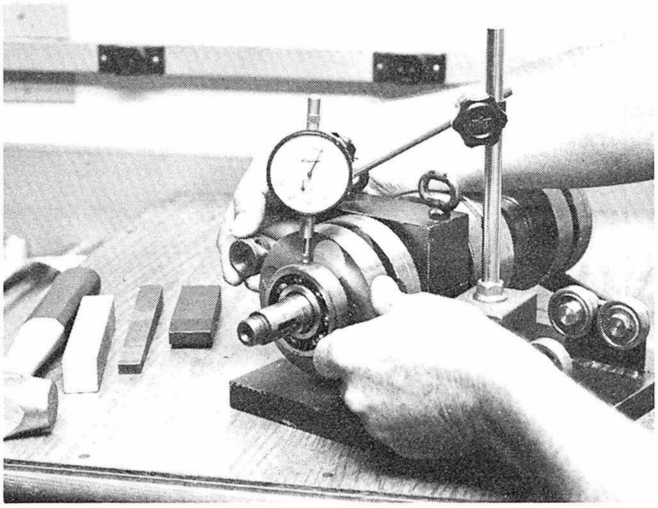

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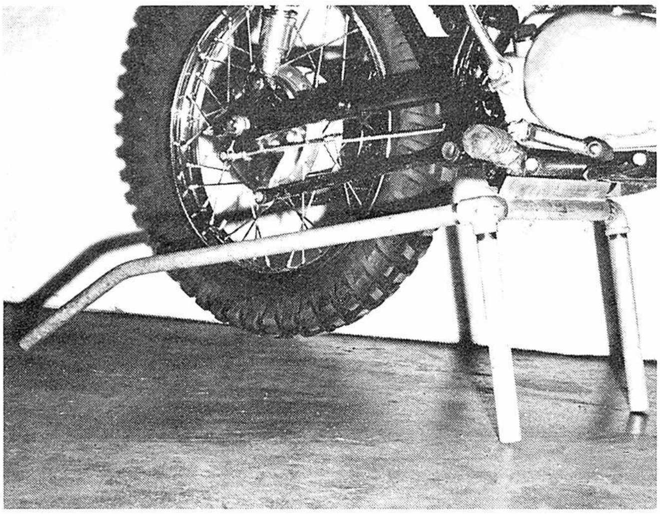

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1. Vise-grip pliers can be a lifesaver when removing stuck muffler baffles. Note curved jaws, some have the less versatile straight jaws.

2. A high-speed polisher/grinder such as this flexible shaft unit, saves much hand labor. Look for a unit with lots of torque and rpm.

3. An ideal home motorcycle workshop should look like this. Plenty of elbow room to work around bike and bench with vise and grinder.

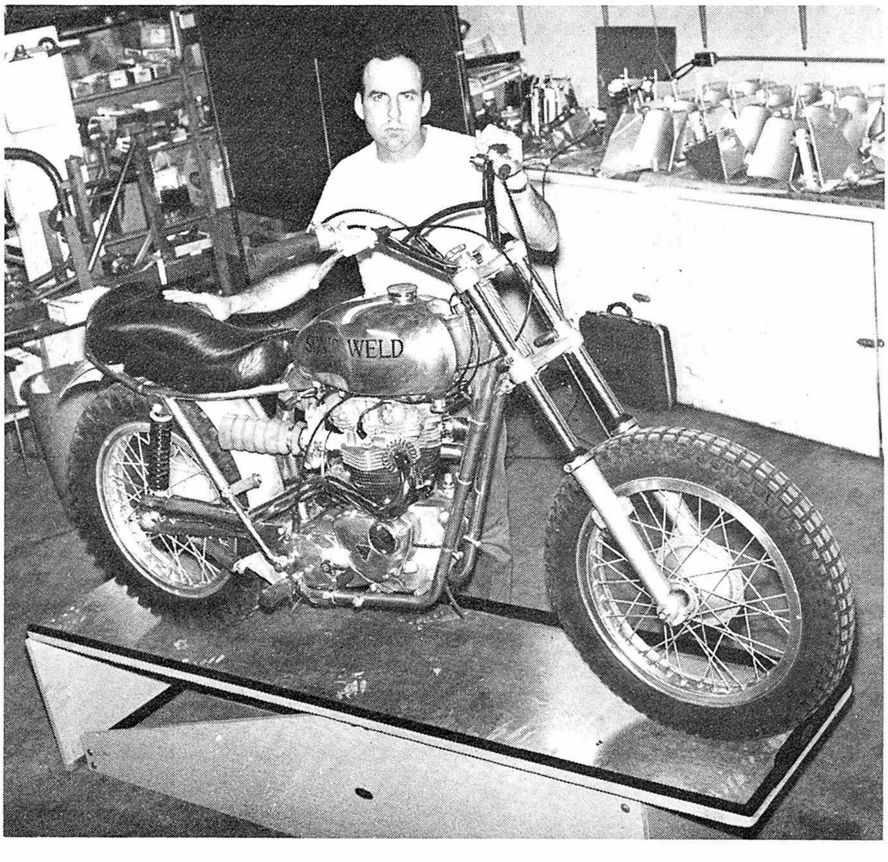
4. Two-stroke or four, an accurate degree wheel is a necessity for the home mechanic. Dialing in a cam is rough without an indicator wheel.

5. Gear ratio calculator solves the math problem when changing gearbox or rear wheel sprockets. Just locate ratio desired and buy cogs indicated.

6. Measuring flat plate, crankshaft supporting V-blocks and dial indicator are used to check the crank end bearing for excessive play.

7. Instant and inexpensive motorcycle lift is what this tube-like thing is. The lift is made from joined pipe tubing and 90° bracket.

8. Super deluxe cycle lift is for those who want the very best. Craftsmanship is first class. It tilts for easy bike loading and off-loading.



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TROUBLESHOOTING

Patience, common sense and taking things in order will locate the simple and complex problems. It only takes a little time

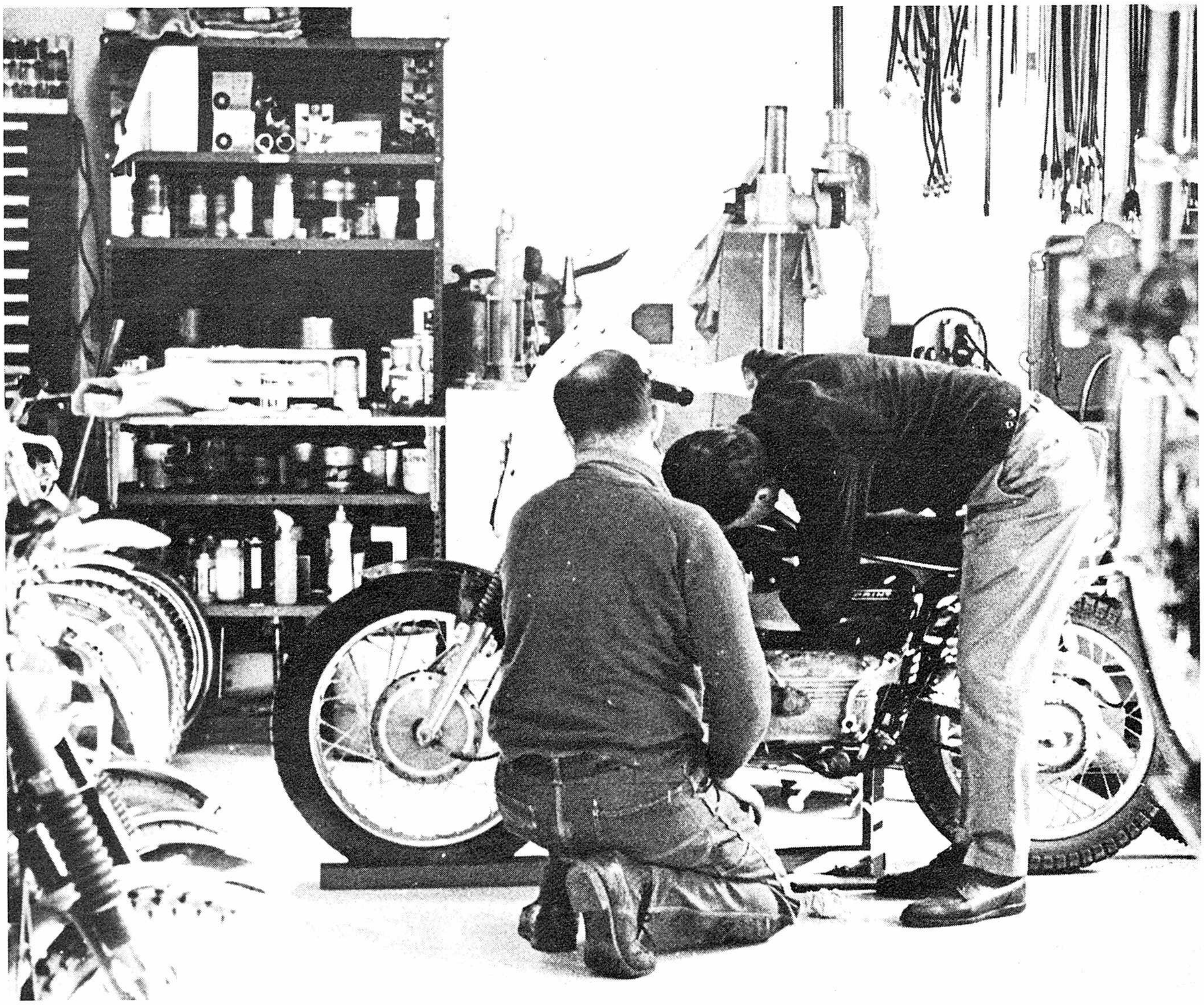
BY MIKE CAPALITE

The big secret of trouble-shooting analysis and correction is to check the easy things first. Keep in mind that no possible fault is too small to check. The tendency for the home mechanic is to think something major is amiss with his machine when it won't start. Riders have overhauled the ignition system to cure a no-spark problem only to find that the spark plug was fouled. Starting out with the easy things, even if it doesn't tell you what *is* wrong, tells you what *isn't* wrong. The beauty of orderly trouble-shooting is you won't be bothered with the thought that you might have missed something that you could have checked out very easily when you have to dismantle the machine.

We will deal primarily with the running of the engine. If you break a drive chain, it doesn't take a mechanic to tell you that it broke. Trouble-shooting other components of the machine can be found in other chapters. We will deal with the most common complaint heard in the motorcycle shop: "My motorcycle won't start!" or "My motorcycle doesn't run right!"

Begin trouble-shooting with a logical approach, and remember this theory: in order to function, an engine only needs three things, (1) correct air-fuel mixture; (2) adequate compression; and (3) ignition at the CORRECT time. If your engine has all three of these, it has to run (famous last words). Joking aside, if the rest of the running gear is in working order, these three things are all that is needed. If you look at your engine problem in this respect, you will find that it will simplify the solution and you will not be checking parts that have no bearing on the problem.

One peculiarity of the two-cycle engine is that it must have compression in the cylinder, as well as vacuum in the crankcase in order to run. Much of the American public has just come into contact with the two-cycle motorcycle engine within the last five years, and they are still in the process



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of learning what they are all about. Many riders don't realize that the fuel from the carburetor is drawn into the crankcase by using the vacuum created in the sealed crankcase when the piston travels upward to the top of its stroke. Then this same fuel which has been drawn into the crankcase (mixed with lubricant to lube the bearings) is forced up into the cylinder when the piston creates compression in the crankcase on its downward stroke.

In most two-strokes, the timing of the compression and passage of the fuel through the transfer ports is controlled by the piston position is relation to the ports. This goes for the exhaust timing as well. There are some who have deviated from this norm on the induction side with reed valves and rotary valves, but the principle of the two-stroke remains the same.

As the two-stroke engine is the type that seems to be gaining in popularity in the United States and as it also seems to have the most mystery about it, that is where we will begin. Let us start with the most common complaint, "My motorcycle won't start, what's wrong with it?"

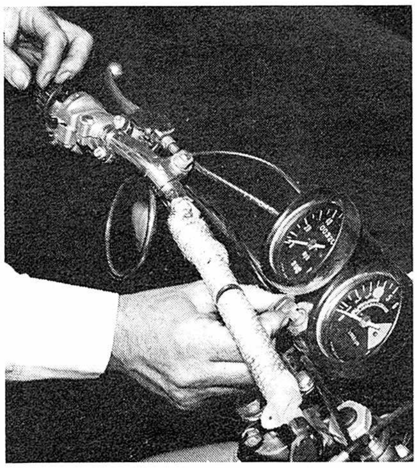
You will usually receive a reply like, "Try turning the key on" and a loud click in the receiver. A service manager could spend all day telling you things that could be wrong with your machine, when it doesn't start. For this reason, you should do a little troubleshooting on your own. Maybe you won't be able to fix the problem, but if you find it, it will be a lot cheaper when you take it into the shop as they will not have to spend the time trying to find it.

When you are troubleshooting for a no-start engine, don't take anything for granted. Make sure that the key is on, and never assume that you have plenty of gas; take the cap off and check. You should have at least a half-tank of fuel when troubleshooting. I knew one rider who practically kicked his leg off trying to start his machine and later found his wife had been sneaking out with the bike while he was at work and riding it. He just *knew* that he had plenty of gas in it, until he found it was bone dry. The best attitude to take is to check out anything, no matter how obvious it may seem.

The next thing to check is for spark. This is commonly done by removing the spark plug and laying it on the cylinder head; turning on the ignition and checking to see if it sparks when the engine is cranked over. This system is fine as long as the plug is not fouled. If it is fouled (shorted out internally or fuel-soaked), the spark will just bleed through to ground and not appear to the naked eye. You won't have any spark. There are three systems for positive checking. I call them, "The wrong way," "The right way," and "The best way." The wrong way is when you hold the spark plug in your hand, kick the engine over, and your eyes light up like a pin-ball machine. This means you have spark. The right way is very similar to the wrong way except that you have someone else hold the plug while you kick the engine over. If they don't jump about a foot off the ground, you know you have no juice at the plug.

My best-way system is best, because sooner or later you will run out of live ones to hold onto the plug for the other tests. What I use is an old Lodge rebuildable spark plug. This was a plug made in England that came apart for cleaning. By taking the inside out of it, you have a section of porcelain with the iron core down the center. You could then clip onto the high-tension lead and still hold onto it without being "bitten." With this plug held up against the cylinder head, you can see the spark jump and see just how good the spark looks.

These English plugs that dismantle are a little hard to come by. Your best bet is to take a regular plug and cut it very carefully with a hacksaw to remove the metal body. Leave the porcelain center intact. With this handy tool as a part of your troubleshooting equipment, you will be able to tell if it is lack of spark causing your problem. If not, you will be able to go on to further checks. If you find



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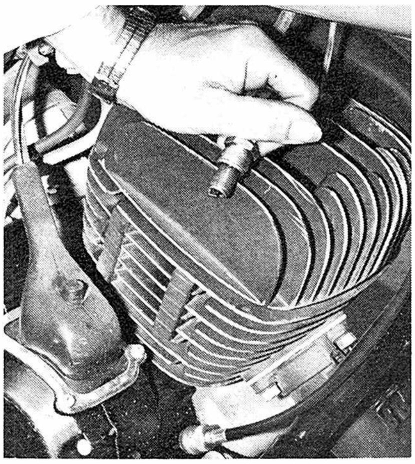

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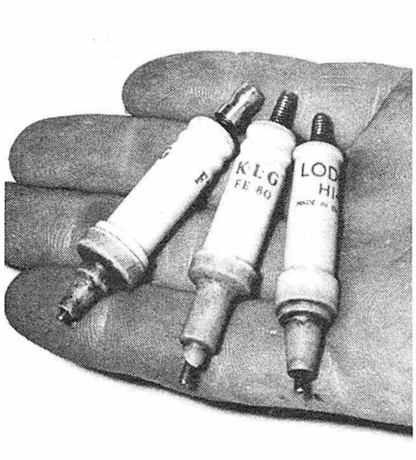

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1. It shouldn't happen to a dog! But it happens to everybody sometime. Knowing the contents of this brief chapter will put you back on the road in no time.

2. We all suffer mental lapses at one time or another. This is probably the most common cause of failure to start, along with forgetting to turn on the gas.

3. This is the real dumb trick, but if you're not the type, better look for leaks or a neighbor with a siphon hose.

4. If you've done everything by the book, the first place to look for real trouble is here. A nice fat spark is what should be seen.

5. These make a good shop-aid for spark testing. They eliminate the plug fouling complication and help avoid unwanted jolts.

that you have a lack of fire, the next thing to find out is why.

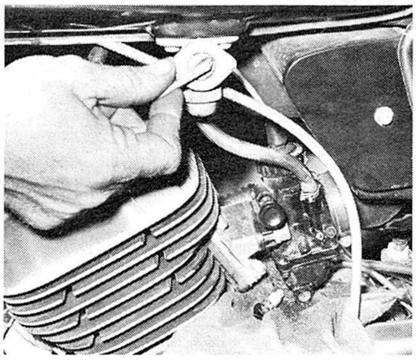
The problem could be a bare wire from the magneto up to the coil or perhaps a bad switch; the impulse from the magneto could be lost anywhere between the magneto and the coil. A good tracing device is a test probe similar to the unit that is sold by a Snap-On Tools. It looks like an ice-pick with a clear handle and has a test lead protruding from the handle. These are nice, but not necessary as one can be made up very simply using a bulb holder (such as used on your neutral or high-beam light). Just the bulb alone can be wired in series to an alligator clip with a wire at one end and a large hat pin or similar sharp object can be made up on the other end.

If you suspect the coil, disconnect the wire that leads from the magneto to the coil (at the coil). Connect the test probe to the wire and the other end of the test probe to the chassis (ground) with the key in the "on" position and kick the engine over. If the bulb lights, you know you are receiving current to the coil; if not, you will have to continue looking. This is where the hat pin comes in handy. It can be jabbed into the wire while looking for current without damaging it. When you find the two points where you have juice and where you don't, the problem must be between the two. A test probe like this is handy for finding any kind of electrical short where passage of current continuity is a problem.

One of the most common complaints with magnetos is when the owner installs a new set of points and subsequently there is no spark. Sometimes forgetting to adjust the point gap is the problem, but nine times out of 10, he has installed them incorrectly. Close inspection will find that he has installed the lead wire to the terminal bolt beneath the insulating washer. Most contacts have a central screw that holds the spring of the moving points and also the wire from the exciter coil and the condenser. This is mounted solid to the other point which is ground. To avoid grounding this connection, the small screw is isolated from the mounting bracket by a large fiber washer, a small fiber insert and another large fiber washer. All this fits through a hole in the mounting bracket so that it is insulated. Where the rider makes his mistake is by sliding the springs or terminal on the end of the wire beneath the fiber washer, thus eliminating the insulation and grounding the points.

Another problem with the breaker points is some foreign matter between the contacts. Inspect the contacts, and if they are dirty, they should be cleaned with a flex-stone. This is a small piece of plastic with an abrasive in it that will polish the points rather than sanding them. After they have been cleaned, take a small strip of index card or business card, open the contacts, insert the card and let the contacts close on it. Twist the card back and forth a few times, then open the points and take it out. Never pull it out with the contacts closed as you may leave a tuft of paper between the points and this will keep them from operating. If you find the contacts pitted badly, then you should replace both the condenser and the points. Metal removed from the stationary point and built up on the moving point indicates low capacity in the condenser. On the other hand, metal built up on the stationary contact is an indication of excess capacity of the condenser. In either case, the condenser should be replaced. Also keep in mind that point gap and ignition timing are very important to magneto performance. They work on the principle of ignition occurring at the high point of the sine wave. You need not concern yourself with sine wave principle, but keep in mind that good performance, as well as trouble-free running of the motorcycle, depend on correct ignition timing.

The CDI (capacitor discharge ignition) magneto is standard on some of the Kawasakis, Suzukis, and many of the Spanish machines. This ignition



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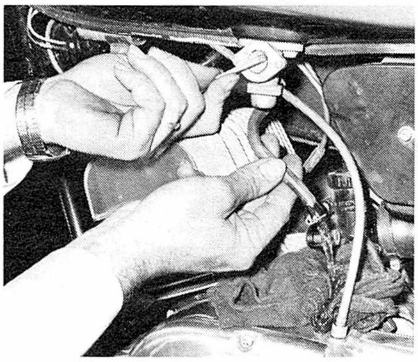

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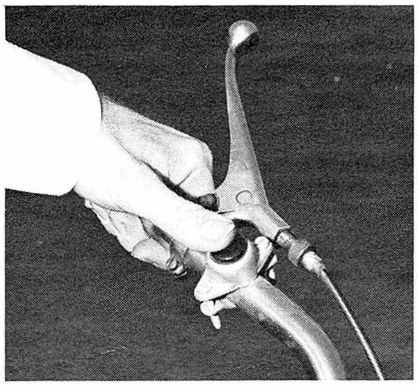

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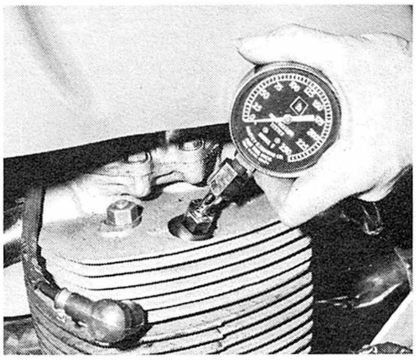

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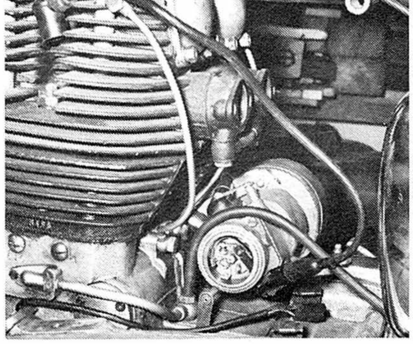

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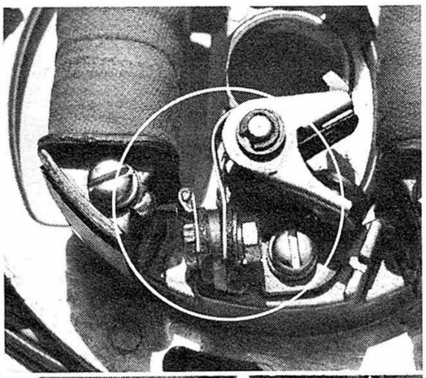
1. A full tank of gas is useless if it isn't getting through. Pulling the carb drain or jet plug will also eliminate any water that may have crept in.

2. If the carburetor comes up dry, make sure the line is clear. Then dig into the float bowl.

3. Kill buttons are the most apt to commit suicide of any part on a bike. The wire leading from here to the coil is also very vulnerable to insulation damage and shorting.

4. A compression check will tell a lot about an engine that is hard starting or rough running.

5. The old-style magneto puts out the hottest spark, but worn brushes will make for erratic operation. Check these out when in doubt.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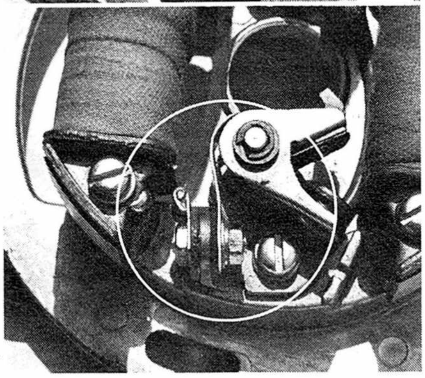
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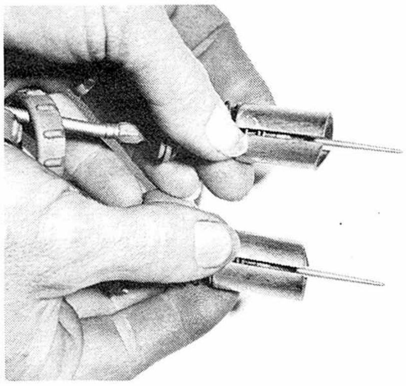
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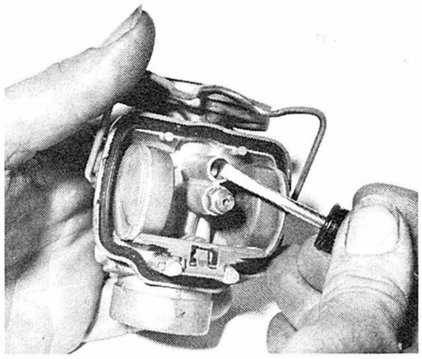
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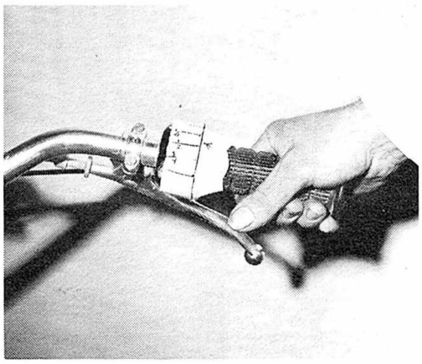
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system makes timing doubly important as it depends on the sine wave for charging the capacitor and triggering the high voltage. Instead of using a cam to open a set of contact points, CDI utilizes an AC voltage surge to activate a thyristor in the circuit that releases the voltage stored in the capacitor. Most problems with this ignition are traced to the CDI (or "little black box" as it is often called), but don't take this possibility for gospel. These CDI boxes are expensive and should only be purchased when you are sure that it's your problem. These are usually sealed and cannot be taken apart and repaired.

Sometimes it's wise to spend a few bucks and have the units checked by your local dealer. Before you do, though, you might inquire as to the cost of having the dealer check it. The reason for this is that a small multimeter that will do the job for you can be purchased from some of the electronic discount houses for about $10.00. They are a handy instrument to have around to trace most any electrical problem.

The ET (energy transfer) system is used on British motorcycles and is basically a magneto. Only instead of being contained in one section of the motorcycle, it is spread all over the place, and prone to more problems than desired. While this system has certain advantages, it too depends on correct ignition timing for best results as far as performance is concerned. Most of these English machines have an automatic spark advance, but if allowed to become too retarded (even though it may start easily and idle fine), it will either misfire or quit altogether when you try to accelerate. It gives the rider the indication that something is wrong with the carburetion system.

6. The wrong way. A common error in point installation is putting the spring under the insulator and grounding it out permanently.

7. The right way. The spring is insulated from the base and the grounding is done through the points.

8. Here's one that can fool some Honda owners. Left- and right-hand slides can be mixed up. The cutaway should be seen from the air cleaner end of the carburetor.

9. It isn't very common but dirt can plug carburetor passages. If you get this far, make sure everything is clear, and the float is adjusted and not leaking.

10. The only way to know throttle position accurately when tuning, is to mark it as shown here.

If the timing becomes too advanced, the rider may find that by pushing it and turning the engine over quite rapidly, it will start and run as long as the rpm's are kept up, but the minute the engine slows down, it will die. Again this is due to it being out of phase. If you are having one of these problems, and you want to make sure that it is a problem of phasing, all you have to do is put a washer beneath the bolt that goes through the center of the point cam. Then lock the advance unit in the position that the engine runs best (i.e., if all it will do is idle, lock the advance mechanism in this position). If the engine now runs well through the entire power range, it indicates that the phasing is incorrect. This could be due to the incorrect ignition timing or wrong rotor location. It could be that the rotor on the engine shaft was removed for some reason and installed improperly. You can imagine a rider's surprise when his machine's engine suddenly acts up after he replaced the primary chain.

CARBURETION

If you find that your non-starting problem is not electrical, you can check carburetion. Again, check out the simplest things first; is there enough gas in the tank? See that the tank is topped up. Then check that the fuel is reaching the carburetor. Remove the gas line at the carburetor while holding a rag or can under it, turn on the tap, and if fuel flows freely, you are all right so far. If the machine runs for a short time and then stops, it's more than likely a plugged gas tank vent or dirt in the gas line. If the fuel flows freely from the gas tank and it still gives symptoms of starving for fuel, it indicates clogged carburetor passages or jets.

If it becomes necessary to disassemble the carburetor, do it on the bench with clean rags. Lay everything out in order as you take it apart so that you will be able to assemble it quickly and easily. Clean all the pieces one at a time with fresh gasoline, blow them off with air pressure and check them for excessive wear or damage. While there is not much that can wear out, you should check the normal high-friction parts like the float needle where it contacts the needle seat. If the needle has a ridge worn around it, this can permit excess fuel flooding and a resulting high float level that could cause hard-starting

characteristics. Also check the slide for excessive wear marks or slop in the carburetor body. If it is badly worn, air can pass around the slide instead of going under it as it should, and it will make it very difficult to get an even idle. When checking the carburetor, keep in mind that there are four stages of tuning and an equal number of adjustments. For instance, if you have a very lumpy idle (which indicates a rich mixture) coupled with excessive exhaust smoke, it wouldn't do any good to put in a leaner (smaller) main jet as this would be tuning for a different phase of carburetor operation.

Zero to ⅛ throttle opening is controlled by the pilot jet, or as it is sometimes called, the idle jet. This jet is rarely changed from what comes stock as the pilot air screw on the side of the carburetor meters the air and not the fuel. On practically all carburetors, this screw is run to bottom and then backed out anywhere from 1¼ to 1½ turns. The best setting is in your riders' handbook and you should be able to obtain an even idle within ¼-turn either way. If you have to deviate from the suggested setting a great deal, you can suspect that something is wrong. As you turn the idle air screw in, the mixture grows richer (less air-to-gas ratio); as you back it out, it lets more air in and leans the mixture. If you have to screw it in almost to bottoming to obtain an even idle, this indicates either the idle jet itself is plugged or possibly there is an air leak between the carburetor and the engine. If the engine has a tendency to backfire when the throttle is backed off, this is an indication of a lean idle jet mixture (this could also be caused by a loose exhaust pipe or flange at the mounting manifold). From ⅛ to ¼ opening throttle, the slide cutaway takes over. This is the angle cut in the throttle slide that faces the air cleaner side of the carburetor. These slides are numbered according to the height of the cutaway with numbers such as 2½, 3, 3½, 4, etc. These indicate richer and leaner slides with the higher numbers being the leaner slides while the lower numbers are richer. From ¼ to ¾ throttle opening, the fuel/air metering is governed by the jet needle and the needle jet. While the needle jet can be changed (it should always be used with the correct jet needle), it is normally kept the same and any changes are made by lowering or raising the needle by relocating the clip in the top of the needle. Last but not least is the main jet size that controls the mixture from ¾ to full throttle opening. Each jet is stamped with a number; the larger the number, the larger the jet, and the more fuel that will pass through. While you must be concerned with carburetor tuning at all four stages, the most common starting problem is a plugged idle jet. The orifice in this jet is very small and it doesn't take much to plug it up.

Some engines can run with very little compression (if they are pulled behind a car or pushed real fast), but you should be able to muster up at least 100 pounds compression on a gauge if you expect your engine to start by kicking. It is hard to give a norm for a compression check, but 150 to 170 pounds is usually pretty good. You should consult the riders' handbook as some of them tell you what it should be, or ask your dealer. When taking a compression check, always open the throttle full when kicking the engine over for a true reading. If the throttle is closed, it will give you a false reading. If you cannot obtain a compression reading, it usually means a bad set of rings. If you have a nil reading, it indicates a bent or burned valve or possibly a blown head gasket. An engine that has been running lean or out of time can have a hole burned in the piston, and this can happen to a two-stroke or four-stroke.

In the two-cycle engine, checking for compression involves more. A bad reading at the spark plug hole may indicate a bad set of rings, possibly a blown head gasket (or holed piston). But you can have a good reading here and still have a starting problem due to pressure leakage in the crankcase. A leaking crankcase on a four-stroke engine just means that it will leak oil and be messy, but in two-stroke, it can mean big trouble. In a two-stroke you must have compression in the combustion chamber and vacuum in the crankcase in order for the engine to operate. One symptom of crankcase leak or bad seals is when you choke the carburetor heavily and kick it over a number of times, but the plug does not become wet. This indicates that the fuel is not being drawn into the engine from a lack of vacuum. If the engine seems to be smoking excessively, this would indicate that the drive-side seal is bad and is sucking oil out of the transmission or primary into the crankcase and causing the oil-rich mixture. If you have trouble idling the engine down and you have to screw the idle jet in to get a decent idle all the way, check for the dyno-side seal to be the culprit.

This covers the common problems encountered when you have an engine that won't start or runs badly. When you are trying to troubleshoot a problem, use logic and common sense, and don't take anything for granted. Try to remember the circumstances surrounding the problem. When did it first start? What did you do just before the problem started? Did you add anything to the machine, take anything off, or change anything that might have caused it? Even if you have to take it into the shop to find the problem tell these things to the service manager to help him locate the cause and cure to the problem.

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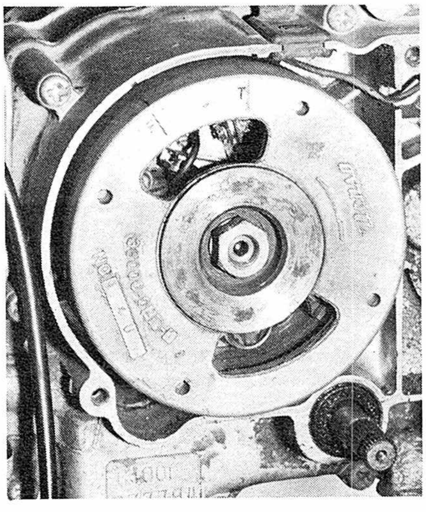

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1. Both point gap and timing are crucial to proper running. On that flywheel, 'F' means fire and 'T' means top (dead center).

2. Inexpensive testers like this one can be used to trace all kinds of ignition and electrical problems.

IF ENGINE DOES NOT START OR IS HARD TO START

(First check that the ignition is on and that there is a proper amount of fuel in the tank.)

1. CHECK TO SEE THAT FUEL FLOWS INTO THE CARBURETOR

IF FUEL DOES NOT ENTER THE CARBURETOR:

Fuel line clogged or damaged.	Clean or replace.
Fuel strainer clogged.	Remove and clean.
Fuel tank petcock clogged.	Remove and clean.
Tank air vent clogged.	Remove and clean.
Flow stopped at float needle.	Remove and clean.
Float setting too high.	Reset float level.

2. CHECK FOR SPARK AT THE PLUG AT KICKSTARTER SPEED

IF YOU HAVE A GOOD, HOT BLUE SPARK:

Faulty plug under compression.	Replace plug.
Ignition timing off.	Adjust timing correctly.
Carburetor float level incorrect.	Adjust to factory specs.
Fuel mixture incorrect.	Reset to factory specs.

IF THE SPARK IS WEAK:

Bad spark plug.	Replace.
Incorrect spark plug gap.	Adjust to factory specs.
Bad spark plug cap.	Replace.
Damaged or cracked high tension wire.	Replace.
Dirty contact points.	Clean and adjust.
Bad condenser.	Replace.
Bad ignition coil.	Replace.
Bad exciter coil in magneto.	Replace.
Low charge in battery.	Charge to full capacity.

IF THERE IS NO SPARK:

Shorted or fouled spark plug.	Replace.
Dirty or wet contact points.	Dry and clean with flexstone.
Blown fuse.	Replace with new one.
Disconnected wire.	Locate and reconnect.
Bad condenser.	Replace.
Incorrect point gap.	Adjust to correct gap.
Short in the wiring harness.	Repair or replace.
Contact points installed wrong.	Correct.
Kill button shorting out.	Repair or replace.
Ignition coil failure.	Replace.
Bad ignition switch.	Repair or replace.
Magneto exciter coil failure.	Replace.
No charge in battery.	Charge to full capacity.
Battery will not hold charge.	Replace.
CDI unit failure.	Replace.

3. CHECK FOR PROPER ENGINE COMPRESSION (CHECK AT KICKSTARTER SPEED WITH THE THROTTLE OPEN)

IF ENGINE COMPRESSION IS SUFFICIENT:

No fuel entering engine.	Air leak between carburetor and engine.
Too much fuel entering engine.	Float level too high; adjust.
Dirty air cleaner.	Clean or replace.
Carburetor slide backwards or sideways.	Install correctly.
Exhaust port or muffler carboned.	Clean out.
Crankcase seals leaking.	Replace.

IF THE ENGINE COMPRESSION IS INSUFFICIENT:

Loose spark plug.	Tighten.
Loose head bolts.	Tighten to correct torque specs.
Leaking head gasket.	Replace.
Warped cylinder or head.	Resurface or replace.
Worn piston rings.	Deglaze cylinder and replace rings.
Rings stuck in lands on piston.	Clean or replace.
Incorrect tappet clearance.	Adjust to manufacturer's specs.
Bad valve seating.	Regrind and reseat.
Bent valve.	Replace.
Valve seized in valve guide.	Replace both.
Incorrect valve timing.	Retime correctly.
Badly worn cylinder.	Rebore to next oversize.
Holed or burned-away piston.	Replace.

IF ENGINE RUNS BUT DOES NOT RUN SMOOTHLY

TURN THROTTLE TO SEE IF THE ENGINE RPM INCREASES

IF THE RPM'S INCREASE BUT THE SPEED DOES NOT:

Clutch slippage.	Adjust or replace clutch plates.

IF THE ENGINE RPM WILL NOT INCREASE SMOOTHLY:

Bad spark plug.	Replace.
Ignition timing incorrect.	Adjust to correct timing.
Dirty air cleaner.	Clean or replace.
Clogged gas cap breather.	Clean.
Clogged fuel line.	Clean.
Water in carburetor.	Clean out entire fuel supply.
Improperly tuned carburetor.	Rejet correctly.
Clogged exhaust pipe or muffler.	Clean.
Improper tappet clearance.	Reset clearances.
Leaking valves.	Regrind and reseat.

IF ENGINE DOES NOT RUN SMOOTHLY AT LOW RPM:

Dirty or sooty spark plug.	Replace.
Improperly gapped spark plug.	Regap.
Ignition timing advanced.	Adjust to correct timing.
Dirty contact points.	Clean and adjust.
Improper pilot air screw adjustment.	Adjust.
Carburetor pilot jet plugged.	Clean with compressed air.
Improper tapped clearances.	Reset clearances.
Defective or discharged battery.	Replace or recharge.

IF ENGINE DOES NOT RUN SMOOTHLY AT HIGH RPM:

Fouled spark plug.	Replace.
Improper spark plug gap.	Adjust to correct gap.
Pitted contact breakers.	Replace.
Clogged fuel line or gas tank breather.	Clean.
Dirty air cleaner.	Clean or renew.
Ignition timing retarded.	Adjust to correct timing.
Clogged main jet.	Clean with compressed air.
Choke closed.	Open it.
Carburetors not synchronized.	Synchronize.
Carburetor float level incorrect.	Reset to proper level.
Oversize main jet.	Install correct main jet.
Jet needle positioned too high.	Lower clip notch in needle.
Automatic advance stuck.	Repair or replace.
Faulty condenser.	Replace.
Faulty coil.	Replace.
Charging system not operating.	Repair or replace.
Bad crankcase seals (2-stroke).	Replace.
Incorrect tappet clearance.	Reset clearance.
Weak or broken valve springs.	Replace.
Broken rings.	Replace.
Valve timing incorrect.	Retime.

IF THE ENGINE OVERHEATS:

Spark plug too hot.	Install colder plug.
Too-lean air/fuel mixture.	Richen mixture.
Low-grade or stale gasoline.	Change to fresh premium gasoline.
Improper ignition timing.	Set to correct timing.
Carbon in combustion chamber	Clean out all carbon.
Oil level too low.	Fill.
Automatic advance sticking.	Repair or replace.
Brake dragging.	Adjust.
Clutch slippage.	Adjust or replace if necessary.
Drive chain too tight or dry.	Adjust and lubricate.

IF ENGINE STOPS AS THOUGH KEY WERE TURNED OFF:

Out of fuel.	Fill.
Spark plug bridged.	Clean or replace.
Fuse blown.	Replace.
Clogged fuel system.	Clean.
Plug wire shorted or came off.	Replace.
Broken or shorted contact point.	Replace.

IF ENGINE STOPS AS THOUGH BRAKES WERE APPLIED:

Seized piston.	Rebore and replace.
Seized crankshaft.	Rebuild or replace.
Seized transmission gears.	Replace.
Seized bearings.	Replace.

IF THE ENGINE STOPS GRADUALLY:

Loose spark plug.	Retighten.
Partially clogged fuel system.	Remove and clean.
Blown head gasket.	Replace.
Loose cylinder head.	Tighten securely.
Bent or burnt valve.	Replace.
Holed piston.	Replace.

SOFT TOOLS

"Plastic" used to be a dirty word, now, no thinking cyclist can afford to be without it

BY STEVE GREENE

Dad had just put the finishing touch on the big black thumper and stepped back to run through the check-off sheet a final time . . . "Rear chain, gearbox, air cleaner, plug, points, spares, primary oil; yep, we're all . . ." His voice broke off, the sentence unfinished. I could tell by the set look on his face that something was wrong, we were in trouble.

The 500-mile National was only hours away now, the stage was set, preliminary markings were up, mileage taken, checkpoints established and the machinery already in motion. There was nothing we could do to stop it, or even slow it, for any emergency. The countdown had already begun and we—Dad's giant 600cc Matchless single and my 650 Trumpet—were dedicated, committed to marking 137 miles of desert wasteland in the next three days.

"There's a crack in my primary case. The oil's running out. I'm dead, Steve!" Sure enough, our last scouting mission over agonizing, boulder-laced Devil's Staircase had center-punched the thin aluminum, and the primary oil supply obviously wouldn't last half a day at the rate it was oozing from the hairline crack down the front of the case. And anybody'd be a fool to venture forth in the no-man's-land that lies ahead with a bike in anything short of perfect mechanical condition. "Oh man," he said, "no welding shops open this time of day and worse yet, no time to pull the case, even if there were a shop open—no way!" Panic reared its ugly head.

Then, through some blessed instinctive reaction to a distasteful situation, my attention shifted from the ailing Matchless to the ready Triumph. There it was . . . the answer, in plain sight, smeared all over the exposed rocker-shaft end in the rocker box. Only the day before I had dried-up a persistent oil seepage with a new RTV (room temperature vulcanizing) plastic by General Electric. If it worked on a hot engine head, why not on a lousy primary case? Sure as shootin' we were back in business!

As fast as it takes to tell, the single had been laid on its side, front end high to allow the oil to drain away from the fractured nose of the primary case, while the raw edges were generously swabbed clean with lacquer thinner preparatory to applying the magic patch. Squeezing it on like toothpaste, the GE Silicone Seal took only seconds to apply, spread to cover with the fingers. The job was done—it couldn't have taken over 5 minutes.

A lot of earth-shaking things had transpired in that brief interval. We had saved the day; the answer to a traumatic situation which would have seriously jeopardized months of planning and layout work came squirting out of a tube. Several hours' labor and chasing around town had been saved and, perhaps best of all, we had cheated the welder out of a ten-spot at least. No, really more important were the in-the-field possibilities that loomed from this simple back-yard find. For suddenly it became clear that the motorcyclist need no longer be vulnerable to a whole class of minor-yet-crippling failures which regularly bring down even the fleetest, best-prepared set of wheels, in the darndest God-forsaken places. It's so good we'll call it Cycle Lib. Stick it in your pocket. Take it with you. Be free.

No more need the cyclist fear a holed engine or primary case, a torn fork boot or a serious engine oil loss anywhere from tank to oil pump. Here at last was a versatile "jelly band aid" that was almost tantamount to having a portable, pocket-size welding torch at your disposal wherever you go.

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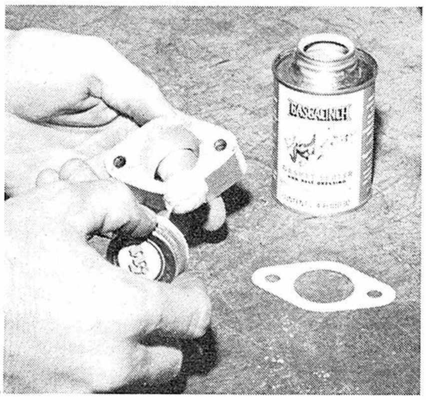

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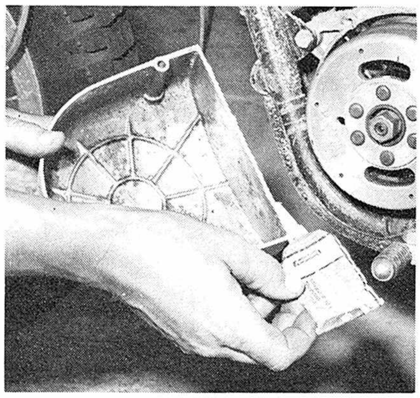

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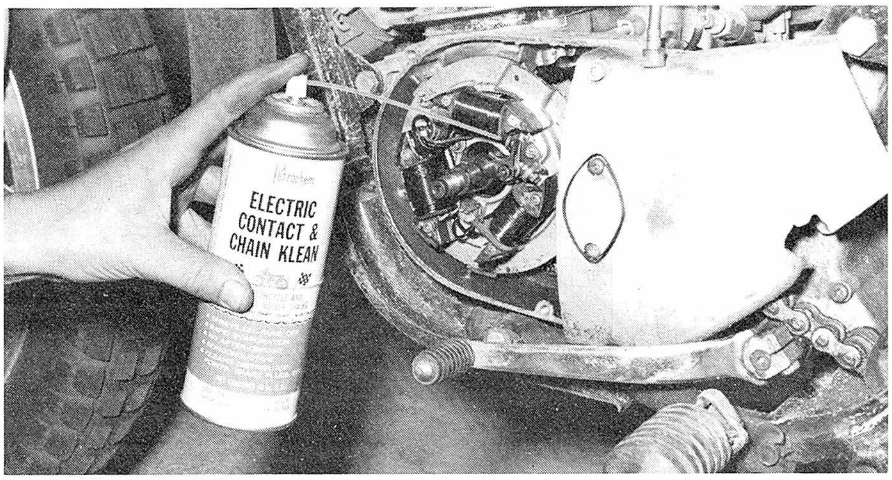

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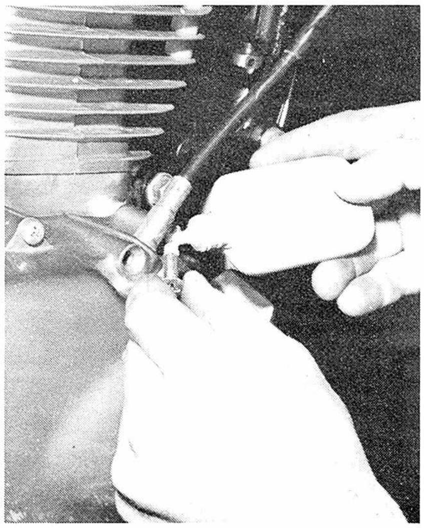

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1. No shop is really complete unless it includes a set of soft tools. They are available in tubes, cans and spray cans and may just save the day.

2. Products like Gasgacinch can be used when installing new gaskets or in place of gaskets. Applied in liquid form, it drys to form air and oil tight seal.

3. Waterproofing ignition systems is a job for silicone sealant. Many types are available from bike and auto stores and can be used all over bike.

4. Spray can ignition point cleaners like this one from Petrochem remove oil and dirt without need for disassembly. Also good for cleaning spark plugs.

5. LocTite manufactures a number of products that are a must around the home workshop. A little applied to a screw before assembly assures that it will never come out till you want it to. They make various grades for various uses.

About the size of a regular tube of Ipana, it can be stuffed in a toolbox or slung on the frame or even carried in a shirt pocket. And with it and half-a-dozen inner-tube rubber bands, there's darned little you can't mend on the spot outside of a broken frame or wheel hub.

Are we over-playing it? After all, plastic patch-kits-in-a-tube have been around since Hector was a pup and at best are only temporary get-by gimmicks that seldom live up to their maker's wild boasts. Wrong, wrong, wrong—on all three counts. The good space-age stuff is only now beginning to filter back to earth; several of the plastics we will talk about weren't available to the public two years ago. And although some of them must be considered temporary, depending upon how critical the application, most of the instances to be cited are not only permanent but provide the best practical solution possible. More important is the fact that, as with First Aid, they can be applied at the time of need, like the best brain surgeon in the world, your favorite welder is of no help if he is not at your side when you're hurtin'. And no longer is the word plastic to be associated with a trinket from Hong Kong; no more must metal be something that can only be formed in a factory. Now the motorcyclist can shape and improvise both of these materials with his bare hands.

Yesterday a punctured case, fractured gas or oil tank in the wilderness meant abandonment or, hopefully, hours, maybe even days at the end of a tow rope, at best an extremely dangerous situation in itself. Today the odds have turned in our favor, and there is every likelihood that the cyclist in distress can ride out under his own power, with a minimum of time lost or danger to his being. It's that great. Inexpensive, easy to use and durable, the new miracle plastics and metals have the added attraction of being readily available at almost any neighborhood hardware store or auto parts house. They're tailor-made for the motorcyclist.

Having been "saved" on this particular occasion, I was moved to explore further into several similar products and their uses. Although they are only a few of the many brands offered, and the applications shown here barely scratch the surface, it is hoped that they will set you to thinking and improvising, in which case the editors of *MSQ* will be interested, I am sure, to bank your findings with ours for future reference in this field of repair. Plastics are extremely simple to apply, the only bit of advice we could give is to clean the working area as scrupulously as possible, using lacquer thinner if available, to remove surface film or oils. In the field this should be done with gasoline, but if this is impractical a dry cloth and some elbow grease will probably do the trick. Remember that most of the included products are best suited as a patch, filler or adhesive, and that sheer-strength is not normally their forte. So experiment, determine their limitations for yourself—you'll be amazed in most instances. Now let's take a closer look at some of the practical applications that first served as the inspiration for this article, and a few others that followed as a result of our continuing curiosity and amazement.

Probably the most versatile of the lot is the GE Silicone Seal that starred in our introduction. A soft, pliable solid, it comes in shades of either white or clear. It seems to have an affinity for almost anything, sticking to and sealing aluminum, steel, rubber, glass, leather . . . you name it. It also sets up rather quickly, becoming dry enough to hold back lightly-pressurized oil (such as in our primary case application) within seconds, and completely curing in 24 hours. One of GE Silicone Seal's features is its tenacity and refusal to run when applied, simplifying vertical applications. It remains semi-resilient and can be peeled off by hand at any time, but resists normal wear and tear. We used Silicone Seal in several different circumstances, all with total success.

Silicone Seal has the ability to withstand some fairly high temperatures; not only did it easily handle the primary case caper, but it proved itself in the cylinder-head rocker box as well, pretty warm country. It stopped dead the aformentioned rocker shaft seepage, a cylinder-base nut leak and a right-side gear case oil mist between crankcase and cover that refused to respond to tightening of the cover screws. None of these applications have fallen off or given up in several

months of extremely hot off-road work during the summer months. Nor has any one of them permitted the slightest sign of oil seepage. The alternative to any one of these solutions would have been the removal of case, cover or cylinder at the expense of much time and no guarantee of equal results. Up until this point, I had been unable to seal off long, obstinate oil seepages, such as are common between crankcase and primary cover, without removing the cover and fitting a new gasket. Silicone Seal has the muscle to do it from the outside, without taking anything apart.

In fact, so unreal was GE's Silicone in its sealing performance that it was decided to give it the super-acid test, that of sealing a gasoline leak. Not wishing to puncture a gas tank, a coffee can was substituted; a hole was first punched in the bottom with an ice pick, then the hole was sealed with Silicone Seal and the can filled with gas. The next morning, the gas was still in the can, the bottom dry. Was there nothing this stuff wouldn't do? This clear plastic rubber was defiant, but I'd break it yet! This time the punctured can was filled with gas first, then while the gas was actually running out the bottom of the can, a wad of Silicone Seal was jammed into the hole. I couldn't believe my eyes! It stopped the leak cold and started to set up instantly! The next morning the patch was still holding, the bottom of the can dry. That did it. There was absolutely nothing we could do for an encore. And the guy who doesn't take a tube of this stuff along on his next excursion just doesn't have it all together—like going off without your sparkplug wrench. Imagine, repairing a split gas tank seam in the middle of nowhere and being back on the road in a matter of minutes!

Have you ever noticed how a headlight often grows dim with age? Dust and moisture gain easy access to the reflector around headlight rim and bulb base, eventually eroding the mirror finish on the reflector. The same can happen to a speedometer; dust blows into the inner workings and speeds wear. To seal the headlight, merely smear Silicone Seal around the base of the bulb while in place in the reflector, then, with the lens and rim mounted back in the shell, force the clear plastic in around the rim, between rim and housing and

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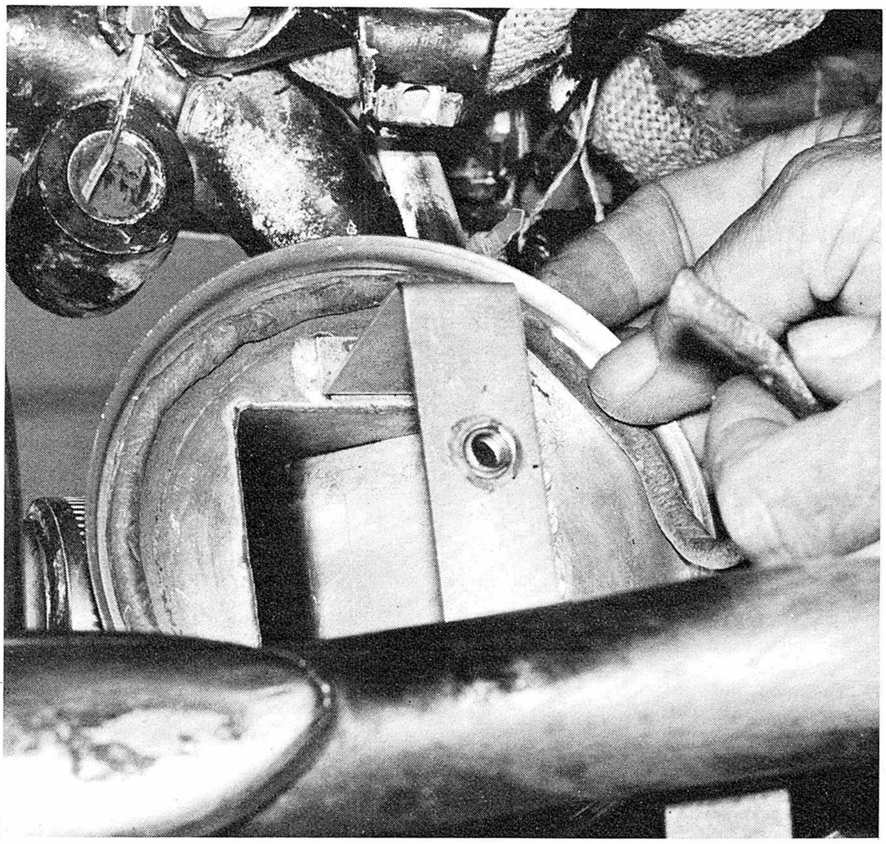

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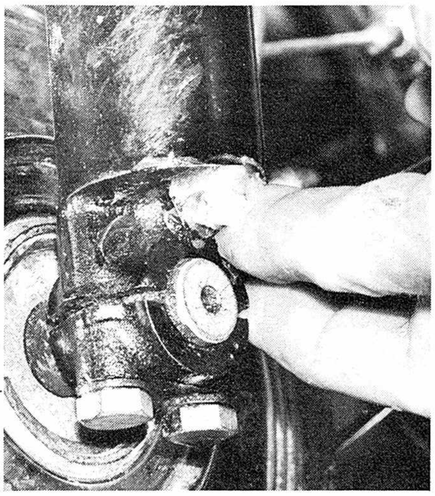

rim and glass, then wipe away the excess. Being clear, it will not be noticeable on glass or chrome, and the lens should be bright as new forever. On the speedometer, the clear plastic can be rubbed around the light socket and also the glass bezel while all is intact.

And with our increasingly worse atmospheric conditions, rubber goods are not long for this world. If the smog or fork springs take a bite out of your fork boots, don't sweat it. You don't have to replace the boot if you don't want to. Why spend an hour and a half removing the wheel and fender, pulling the old boot down off the leg, greasing a new one and slipping it back in place before refitting wheel and fender again? Cycle Lib to the rescue! Just clean the surface, whip out Silicone Seal and cover the hole. A similar tear from a greasewood bush, patched in this matter, survived two months of desert riding and is still going strong, standing the torment of a constantly flexing accordion fork boot and looking for all the world as if it is going to go the route. Fork covers aren't cheap; this stuff is, and quick to boot.

The possibilities are seemingly endless. A torn saddle cover, an electrical connection, or a surface tear in a tire casing; all can be made to lie down tight with this stuff. Often a snag from a rock will peel back the thin outer skin of rubber that covers the first layer of cord in a tire sidewall. Although the tire is not physically weakened (unless the cord is torn too), subsequent exposure to smog, water and dirt will prematurely rot the cord. But a cover of Silicone Seal will permanently protect it from the elements and preserve the tire as though it had never been violated.

Another company which has made the motorcyclist's life a little easier is the Devcon Corporation. They manufacture several products which will heal many of your motorcycle's ailments. Their claim to fame is a product called Plastic Steel. It comes in

a small tube along with a companion tube of hardener and boasts of being "the strongest, toughest repair material available today." It is an epoxy resin that contains plastic and steel and bonds with a multitude of metals including iron, steel, brass, bronze and aluminum. It is not recommended for temperatures above 250°, so let your hot little barrel be your guide. Hardening takes two hours, but can be accelerated with low heat.

Besides Plastic Steel, Devon comes up with Liquid Aluminum, Rubber, ST-50 (Steel), and 2-Ton. The 2-Ton product is an "epoxy super glue" and Devcon states that two drops of this potent mixture will hold two tons! Got anything on your scooter that's about to fall off, like a hand grip, taillight lens, foot peg rubber, exhaust guard, etc.? A few drops of this brew ought to do it ten times over—just be sure not to get a patch of it between tire and ground or you might need a crane to pull it loose! The Liquid Aluminum and ST-50, when hard, can be drilled, sanded and painted. Both set up in two hours. The ST-50 can also be threaded! It could come in handy should you strip a bolt hole in an engine case; just wash it out, squirt in some ST-50, let it harden for two hours and tap the hole with a fresh set of threads.

The Liquid Aluminum can also be used as a backup to GE's Silicone Seal regarding a cracked aluminum outer case or punctured steel case. The Silicone can be used to seal the opening until such time as routine maintenance requires that the cover be removed, upon which occasion the inside of the cover an be treated with the more permanent Liquid Aluminum. After removing the cover, clean it, then rough it up and apply the plastic alloy and it's fixed for good. Just for good measure, depending upon the severity of the fracture, both outer and inner surfaces can be filled, and since it is a non-stressed area, the plastic patch should serve the purpose as well as a weld. Common sense must be used, however, for it is doubtful that one of the plastic metals would hold on a cracked fender, for example, because of the vibration factor and lack of grip area between the broken edges.

Devcon's Rubber is also a versatile product that remains flexible and resists oil but is not up to gasoline. It does an excellent job of mending rips in a saddle or fork boots. Or if that plastic tank badge on your gas tank persists in cracking and loosening or falling off, the Rubber will help secure it even if the screws should wind out due to vibration. The Rubber also is a natural in reference to electrical connections. Since we all encounter dust or water, it is a good idea to seal electrical terminals with this product, as well as beefing-up wiring insulation at potential friction points around forks and tank to preclude shorting-out from inevitable wear—a natural for waterproofing magnetos, etc. Since it is oil resistant, the Rubber could also be employed to secure a rubber oil-line-to-pipe connection by smearing a little on the pipe prior to slipping on the hose, further ensuring against the loss of oil by building up

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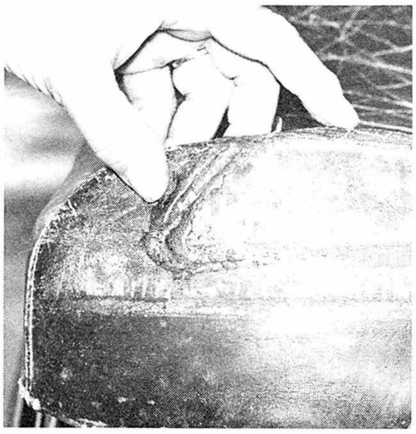

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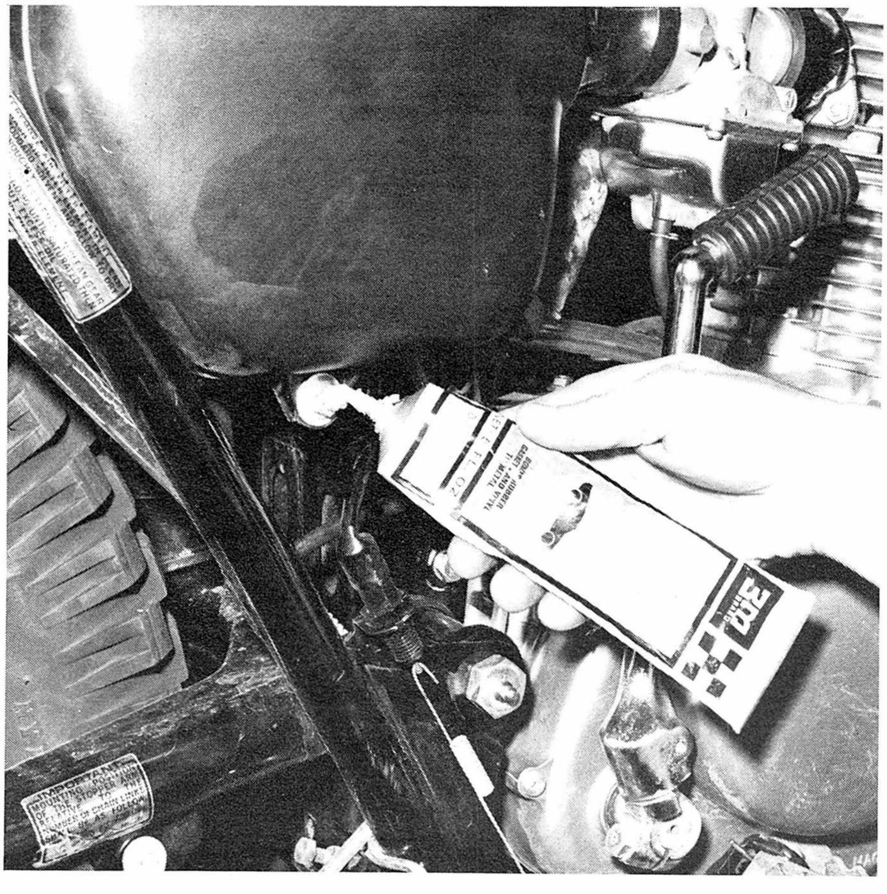

1. Scotch-Calk is like plastic taffy, can be used around the air cleaner backing plate when hard paper element is used, to seal leaks behind filter.

2. Worn fiber washer on fork drain plug can be replaced or Silicone Seal can be substituted. Drys to become plastic rubber that defies even gasoline leaks.

3. Even tires can be repaired with the magic Silicone Seal. This sidewall was returned to like new conditioning with just a small dab after cleaning.

4. Devcon Rubber, one of their many tough products, was used to repair a V-shaped tear in this well-used seat. After drying, the seat is tough as new.

5. Minnesota Mining & Manufacturing have been the motorcyclist's friend for many years. Their "3M," or yellow peril, is found in the toolbox of every racer in the country. Primarily intended for weatherstripping, it does everything.

around the end of the hose from the outside once installed. Footpeg, kickstarter rubbers and handlebar grips can also be kept in place, held from sliding off or even turning by the super adhesive. Smear it generously on the shaft, then on the inside of the rubber, and jam it home—a little messy to work with but it gets the job done.

The Minnesota Mining and Manufacturing Company has pioneered its share of versatile products that can be applied to motorcycles. Their one product which really excels, and I have used for years, is Super Weatherstrip Adhesive. It is so tough that I have nicknamed it Yellow Peril because of its tenacity. This gooey yellow substance sticks to everything it comes in contact with, including your fingers. By the same token, it's one of the motorcyclist's best friends, for it will hold any nut or bolt in place against the most extreme vibration—especially good for the off-road enthusiast. Spread it on the threads, prior to installing the nut, and forget about it coming off . . . until you put the wrench to it. For despite its ability to hang in there, Super Weatherstrip gives away to a wrench and has no damaging effect to threads. And like GE's Super Silicone, it is very good about stopping an oil leak around a cylinder-base nut or oil-line flare-nut fitting, although it seems to be less versatile when it comes to sealing a crack in a case or the long parting line between a case and a cover usually served by a gasket.

Another little helper from 3M is their Scotch Calk, a tacky gray plastic that is packaged in long strips. It never changes its putty-like consistency, neither softening nor hardening, and is ideal for forming around such places as carburetor tops and the like—a good dust-proofer. Scotch Calk is waterproof and fuel resistant and can be reshaped and reused indefinitely. A favorite application is between air filter element and outer cover, to preclude the entry of dust that might otherwise sneak around the filter element rather than through it.

Leaving the subject of preventative maintenance, let's check out the sheetmetal department and see how the wonderful world of plastics can again come to our rescue. Nobody's perfect, and one of our family—I'd rather not mention any names—recently had occasion to lament a fist-sized depression in an up-to-now-cherry oil tank. That was bad enough, but trotting it around from one auto body metal shop to another, in search of a repair estimate, turned up another disappointing fact: because of the small job, and even considering the ridiculously high price of $25 to refill the depression, sand and repaint it, none of the shops really wanted to bother with it. One finally did, and after a week and a half it still sat in a corner covered with overspray from the more lucrative car jobs. In desperation, the oil tank was retrieved, with the sworn oath: "I'd rather do it myself than suffer this hassle." Sure enough, it wasn't all that difficult, and the backyard result turned out as good as any professional shop could have attained. Although there are many fine body filler products on the market, we picked up a tube of 3M's Acryl-Blue Spot Putty (part No. 5960) and a borrowed body rasp and went to work. After sanding to bare metal on the tank, the putty was applied in layers of about 3/16-inch per application, letting it dry overnight between build-ups until the area had come out to slightly past the original contour, to allow for filing. When the surface was restored, it was contoured with the body rasp, then sanded down with coarse paper, finally ending up with No. 600 paper and wet-sanded to a smooth finish. Several coats of excellent Krylon spray paint, available in most hard-

1. Silicone Seal can also be used to prevent dirt or water from entering the delicate items like headlights and taillights. Once dry, there's no way that the bad stuff can get into the works.

2. Petrochem's Anti Rust comes in a spray can and will prevent corrosion build up. Any spare parts laying around the shop can be sprayed for protection.

3. On some machines there are certain areas that will seep some oil after hard use. This Triumph rocker arm shaft was sealed with Silicone Seal in a minute.

4. Devcon Liquid Aluminum was used to repair this broken primary case, saving the cost of a welding job. Once the crack was clean and roughed up with sand paper, the sealant was applied and allowed to dry. That's all it takes.

5. Spark plug caps can be made to stay on forever with a dab of Loctite Lock N' Seal. It only takes a minute and will stay intact indefinitely.

6. ESP is yet another product from the people at Petrochem. It cleans away any corrosion and lubricates at same time.

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ware stores, provides the glossy black finish to this strictly amateur effort that couldn't be told from new.

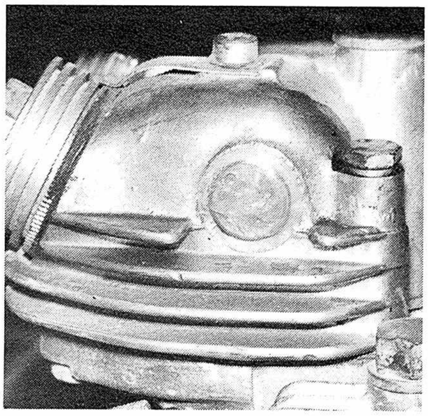
What's next? Let's say it's Saturday night before the club road run, and close inspection shows the old heap is in need of a fresh gasket. Can't buy one. Shops are closed. Never fear, Loctite's here. One of the Loctite Corporation's anaerobic adhesives can make a custom gasket of any configuration as fast as you can lay it on. The product is called Fit-all Gasket, which replaces soft gaskets. Fit-all Gasket cures overnight if you use Loctite's Klean N' Prime, which speeds the cure of all Loctite products and assures part-use in half an hour. Some of Loctite's products can be cured in 15 minutes at 200°. Still another product similar to Fit-all Gasket is Plastic Gasket, which replaces paper gaskets; it is completely water- and air-tight. Two more materials vital to motorcyclists are Lock N' Seal and Nutlock. Both secure nuts, bolts and screws firmly in place so that they won't vibrate out, while Lock N' Seal has the added advantage of being able to seal leaks at oil, air and gasoline fittings.

Loctite anaerobic adhesives are kept wet by the presence of air, but when the liquid is placed between close-fitting metal parts, it then hardens into a solid resin because it is out of contact with the air. Put it on a nut and bolt and, as a liquid, it conforms to the microscopic surface roughness. Later, after it has hardened, the solid is actually keyed to the two opposing surfaces, with the result that the two parts can be separated with the use of ordinary tools but defy accidental loosening.

Going back to our previous situation calling for the need of a new gasket, let's assume that you have the critter but need some way of sealing it because previous experience has proven that, due to surface irregularities or whatever, a positive oil seal is difficult to achieve. The Porter Manufacturing and Supply Company has solved the problem with a product they call Gasgacinch. Again make sure all surfaces are sanitary, then swab-on Gasgacinch to both sides of the gasket and both mating surfaces of the metal, let it all become a little tacky, then assemble. Properly done, your oil leak worries are over.

Still another neat little product is the Hercules Chemical Company's All purpose Tape Dope, made from Dupont Teflon. Actually it is a pipe-joint compound incorporated in tape form that lubricates and rust-proofs large threaded joints or even fuel line fittings. Tape Dope withstands temperatures from −450 to +500°F. It is ideal for such applications as motorcycle fork-bearing seal-cups, helping not only to seal against leaks but also to lubricate the threads as well. It never hardens, and prevents corrosion.

And there are more. The plastics mentioned and shown here are only those which I have "discovered" for personal use. Most of them have counterparts by other companies, possibly equally as versatile and durable, and at least worth trying since all are relatively inexpensive. You'll want to make your own discoveries, no doubt, for the trick lies in the imaginative application to the task at hand. Let's just hope that yours will be under more leisurely circumstances. The age of miracles has arrived. But who ever thought it would come in a tube!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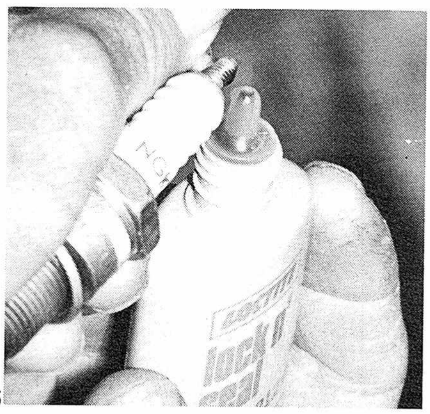
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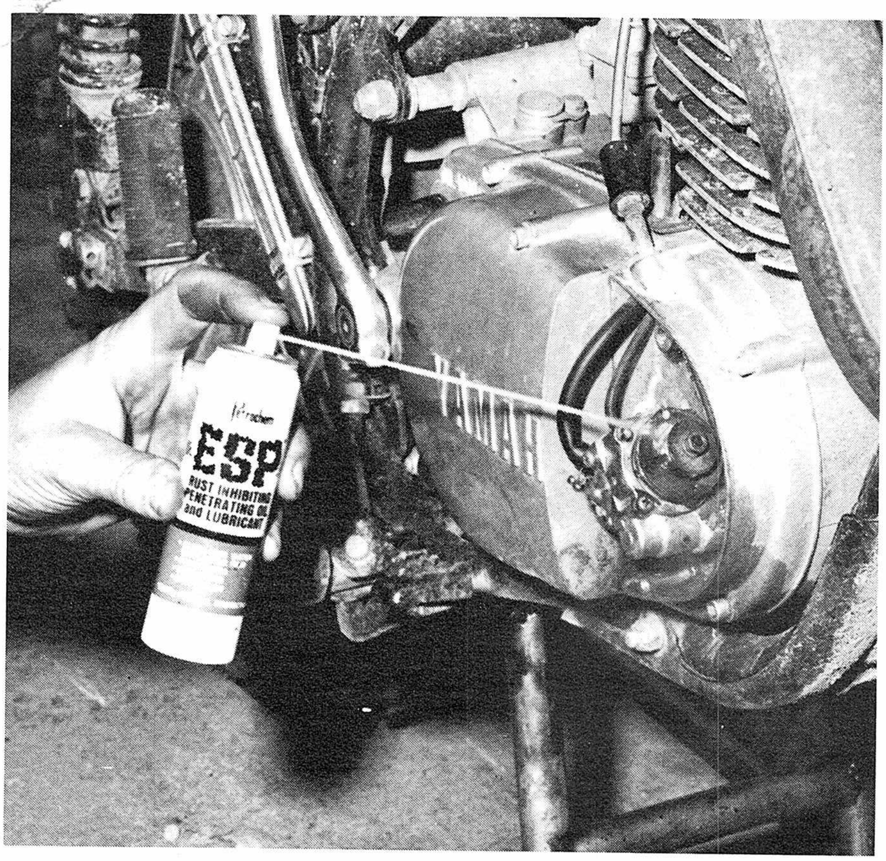

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MINOR ENGINE TUNING

The following sections will more than likely deal with your specific machine, or be easy enough to adapt to your particular model

BY MIKE CAPALITE

There comes a day in the life of every bike engine that things don't seem to be quite what they should. Just like people, they get those spells where food doesn't taste right, digestion is all loused up, lungs are congested or the nervous system is all out of control. Unlike people, engines don't have the ability to heal themselves, and medicines, potions, elixirs and additives won't cure their ills either, contrary to some claims and beliefs. At the onset, most engine disorders are hardly noticeable, but in time they grow to have quite an effect on operation.

The strangest thing about these ills is that they are contagious to the extent that they bring about a change in the habits of the rider. An engine that always started with two kicks gradually works its way to being a three-kicker. The bottom end of top gear was 60 mph but has now gone up to 65, and the rider doesn't even know it. He just keeps on running the bike by the seat of his pants and all the time the engine is saying: "I'm tired, tune me!" This is a common phenomenon, so when you start becoming aware of these symptoms don't ignore them. You may suddenly find yourself in a situation where the chapter on "Troubleshooting" is your only out, and if you don't keep this book rolled up in your hip pocket, start walkin' baby!

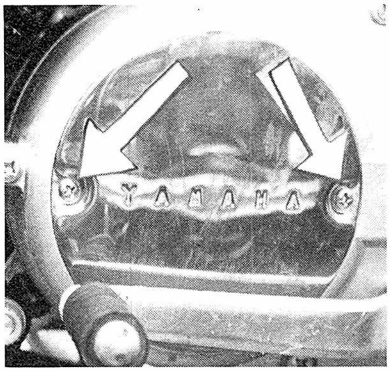
Keeping your engine in sharp tune is no more trouble than a Saturday night bath combined with a toe-nail clipping job, and about once a year is all it needs if you're a seasonal rider. Year round riding or long-distance touring demand more frequent attention if you want to maximize performance and economy. In this chapter we have included detail tune up procedures for 13 of the most popular bikes, and if your bike isn't here don't fret. An example of almost every type of ignition system and carburetor is shown here and if you read through a few of these procedures you'll find them all quite similar. The owner's manual for your particular model should provide the detail specifications for timing and carburetor settings, and the tools and gages shown are common to all types of engine tuning.

Motorcycle engine tuning embodies all the principles of car tuning only it's a lot cleaner and simpler. If you've never done any work like this before, then the bike is the best way to learn the basics. Should you feel a little uneasy about starting out, look around the neighborhood for some cycle enthusiasts to help you or acquaint yourself with the people at some small bike shop where they'll let you in back to shoot the breeze with the mechanics. A little confidence is all you need, and when you see that it still runs after you've tinkered with it, you'll feel renewed enthusiasm for riding on two wheels.

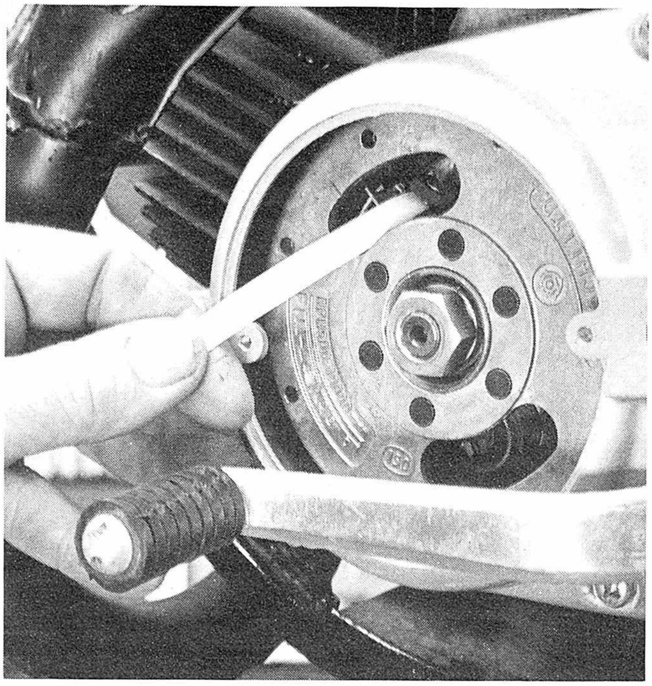
YAMAHA MINI-ENDURO

The tuning procedures can be adapted to all Yamaha's 50 and 55cc rotary-valve models, their 80cc lightweight and other lightweights without electric starters

If there is one model in Yamaha's "Enduro" series that needs constant attention paid to preventative maintenance, it is the Mini Enduro. This 60cc scaled-down motorcycle is powered by a rotary valve two-stroke and is usually ridden by eight to 10-year-olds who just pile on it and ride. When it stops running, they call good ol' dad to fix it. A little time spent checking it out may prevent a ruined weekend outing. Nothing is more exasperating than driving out to your favorite spot in the boonies, unloading the bike and discovering after a few minutes that "it isn't running right." Here are some important pointers to keep the engine running smooth and troublefree.



1. To inspect the contact points, this chrome cover must be removed. After removing the two screws, a light tap will suffice to drop away the cover. The flywheel then can be rotated to a position where the points can be inspected through holes.



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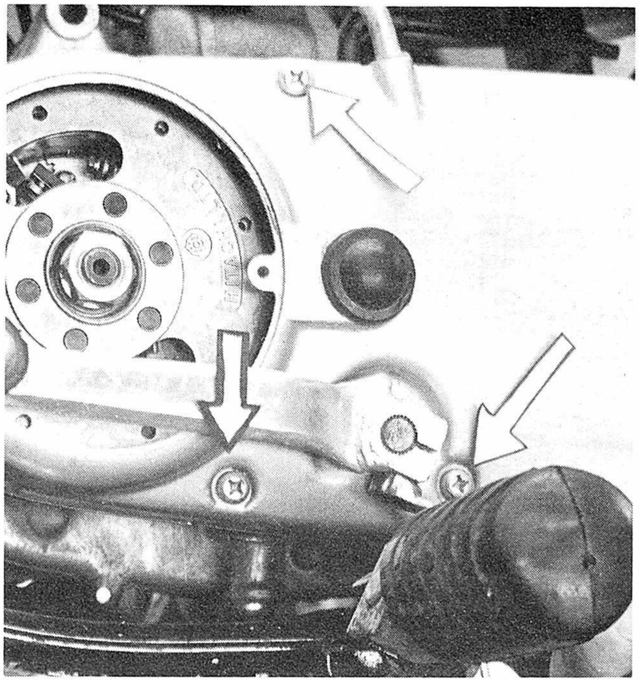

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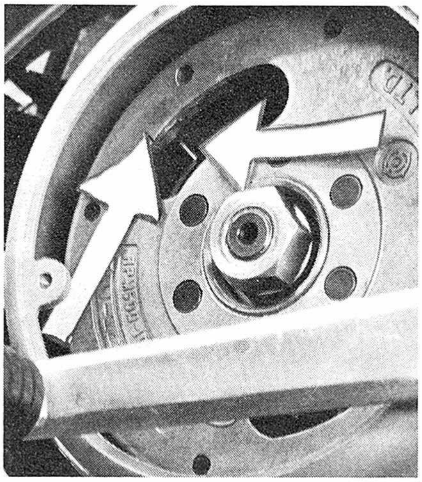

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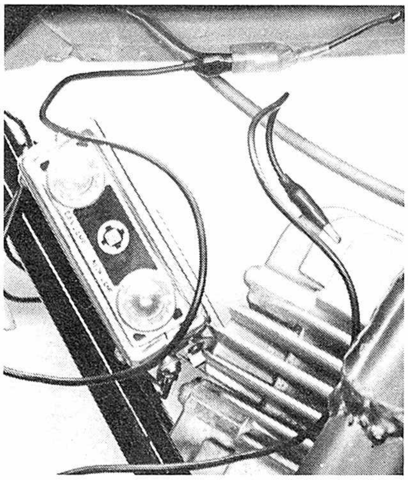

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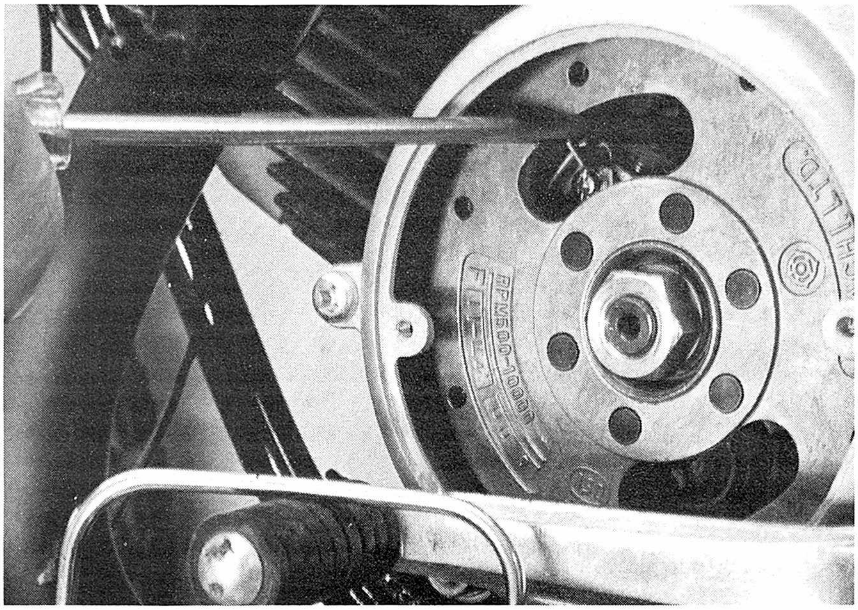

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2. Points can now be checked and if necessary, cleaned with a "Flex-Stone" (available at auto parts stores). Finish by inserting a piece of index or business card between the points and twisting it back and forth. Open the points and remove card. Repeat until card comes out clean.

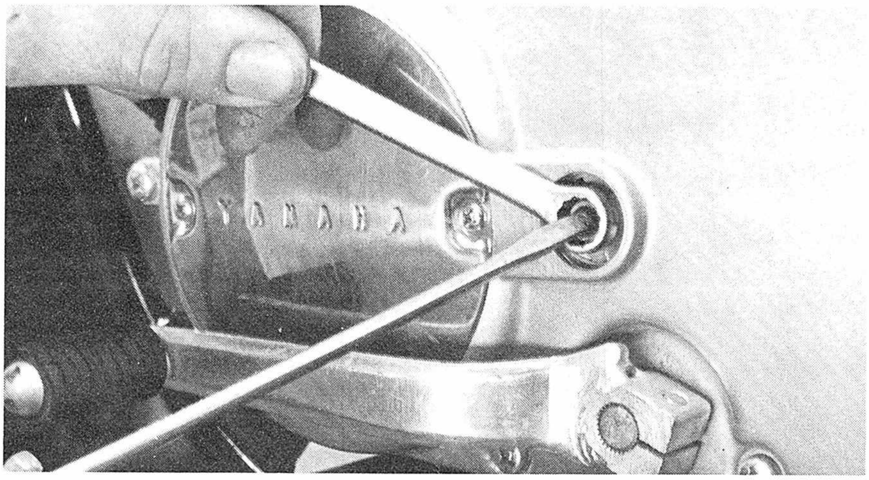
3. If contacts have to be replaced or the flywheel pulled, the larger side cover must be removed. To do this remove the pinch bolt from the gear lever with a 10mm wrench, then undo the four screws indicated by the arrows.

4. After cleaning or replacing the refit the flywheel and secure it. Rotate it until the mark on it aligns with the stationary pointer (right arrow). At this point, the contacts should just break for correct timing.

5. To check when the contacts are breaking open, it is best to use a "buzz box." Reach under the gas tank and find the wire that joins the mag, coil and kill button. Disconnect the coil wire and hook up the tester to it. Hook up the other wire on the box to ground. After you have finished, remember to reconnect wire so the engine will start.

6. When setting the points, your only means of adjustment is to adjust the contact gap. The reason for this is that the point plate is fixed to the engine; there is no means for rotating it. The only way to achieve correct timing is to open or close the gap until the contacts break when the two pointers line up.

7. Remove the rubber plug just to the rear of the magneto cover for access to the clutch adjustment. Loosen the lock nut while holding the screw in position as shown. Run the adjusting screw in until you feel pressure. Back off ⅓-turn, hold in place and lock the nut down.



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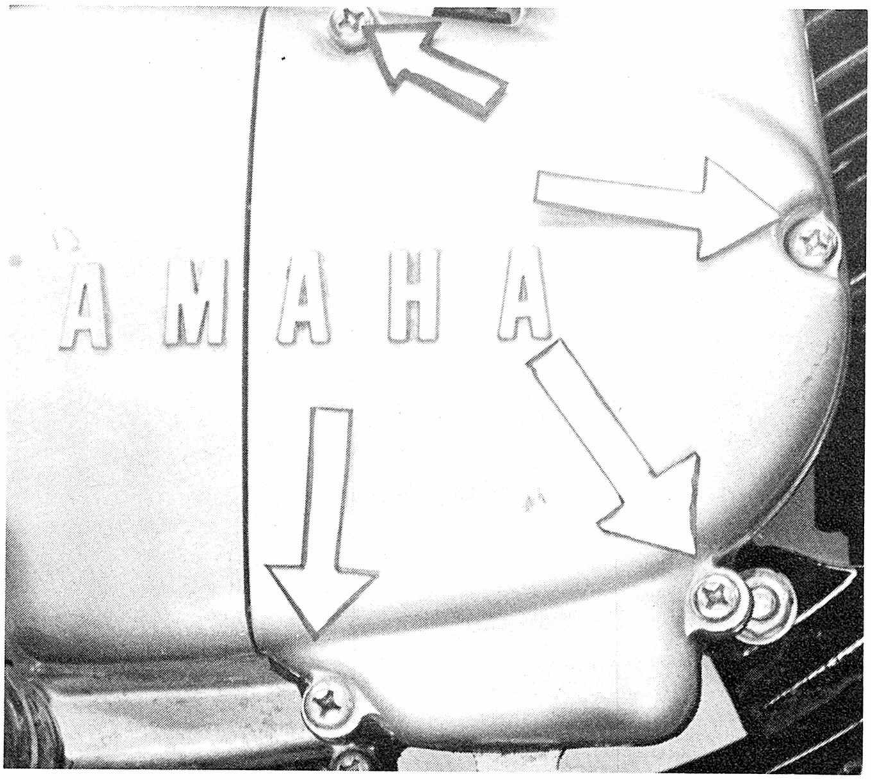

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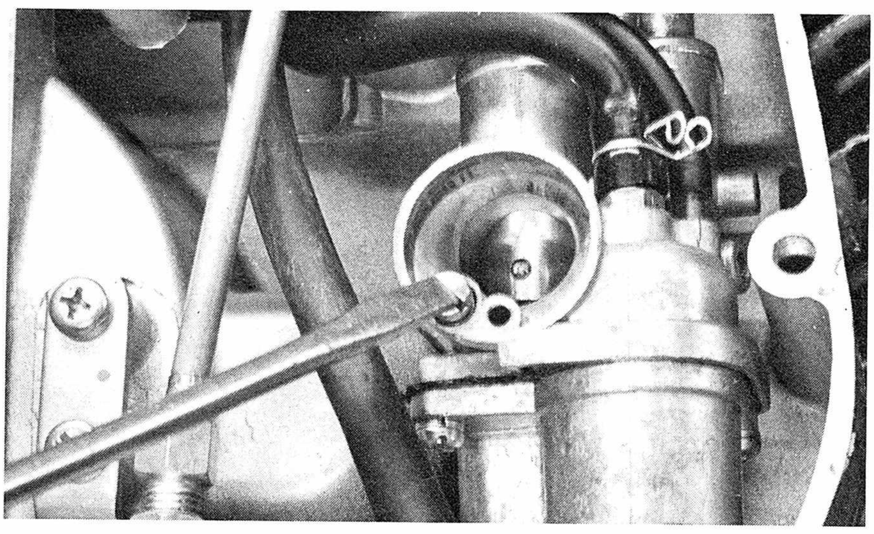

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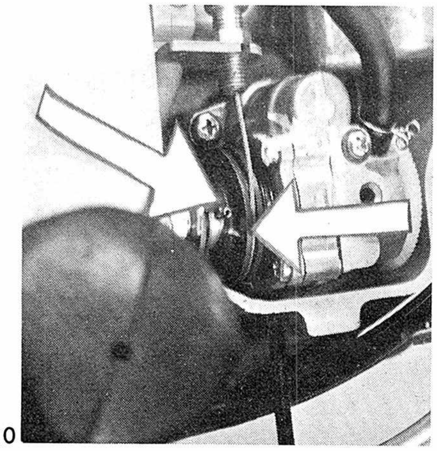
8. This engine uses rotary valve induction and oil injection, so move over to the right-hand side to check these components. Both carb and oil pump are located inside this cover. Remove the four screws (arrows) and it will come off.

9. Adjust the idle air screw by turning it in until it hits bottom (lightly), then back out 1½ turns. Note small drill mark on air slide of carb; this is used to set the oil pump output. Using the twist-grip, open the slide until the top of this mark just comes to the top of the carb's venturi.

10. With slide in this position, the mark on the pump cable wheel and the stopper pin should be in alignment (arrows). If they do not align, set them by adjusting the cable adjuster on the oil pump cable (visible here).

11. Replace all covers, install a new spark plug and start the engine. To set the idle, turn the knurled knob at the top of the carb up or down. After idle is correct, take up any excess slack in cable with the adjuster.



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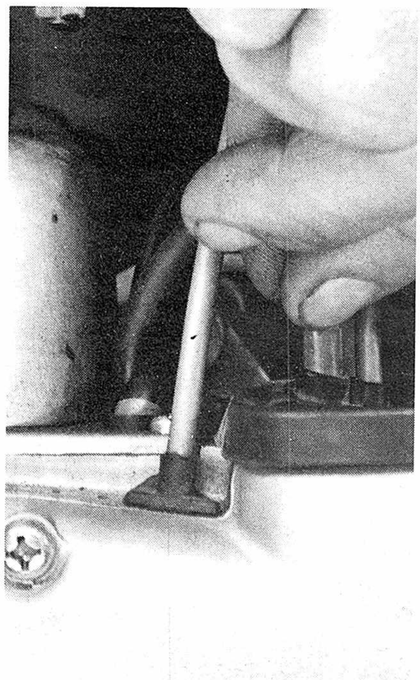

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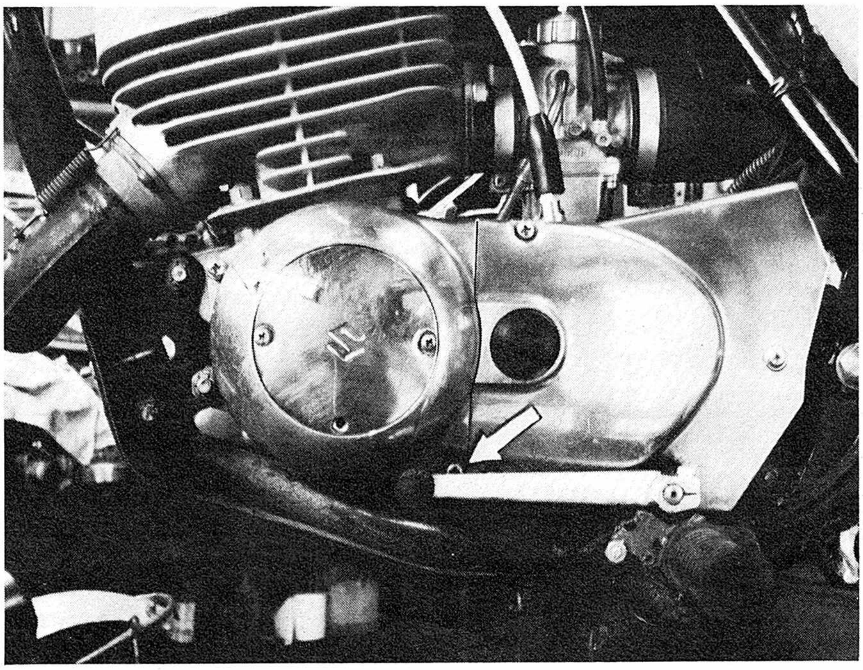
SUZUKI TS-250

For ignition timing procedures, the TS-250 is basically the same as the other Suzuki lightweights with magnetos—only the specs will change

The "enduro" field has become a boon to motorcycle manufacturers, and the TS-250 represents Suzuki's major effort in this highly competitive field. A legion of fans attest to Suzuki's success with this model. Like any motorcycle, especially one that is used for both street and dirt riding, it does need preventative maintenance to keep it in top shape. The engine is a conventional piston port two-stroke with flywheel magneto. Thus, tuning procedures are easily mastered. A dial indicator (to set ignition timing) is preferable but not absolutely necessary. The timing can be checked and adjusted with the use of a timing light. A flywheel puller, however, is an absolute must and the need for this tool (to remove a magneto flywheel from the engine) cannot be stressed too highly. Let's begin.



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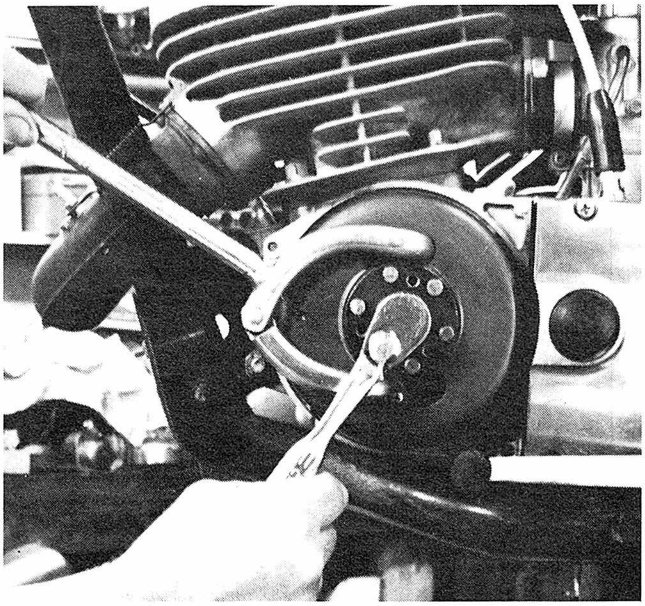

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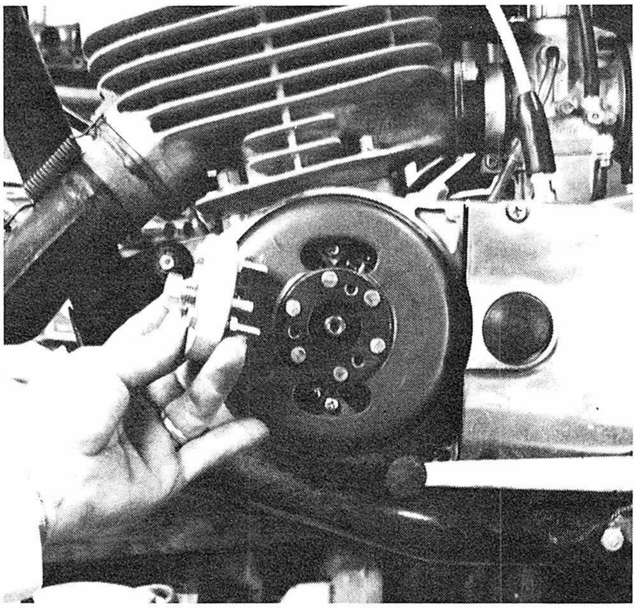

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1. Access to the flywheel magneto is acquired by removing the left side case cover. Remove the two phillips screws and take away the cover. The outer tin plate is merely a visual inspection cover and does not provide sufficient space for maintenance.

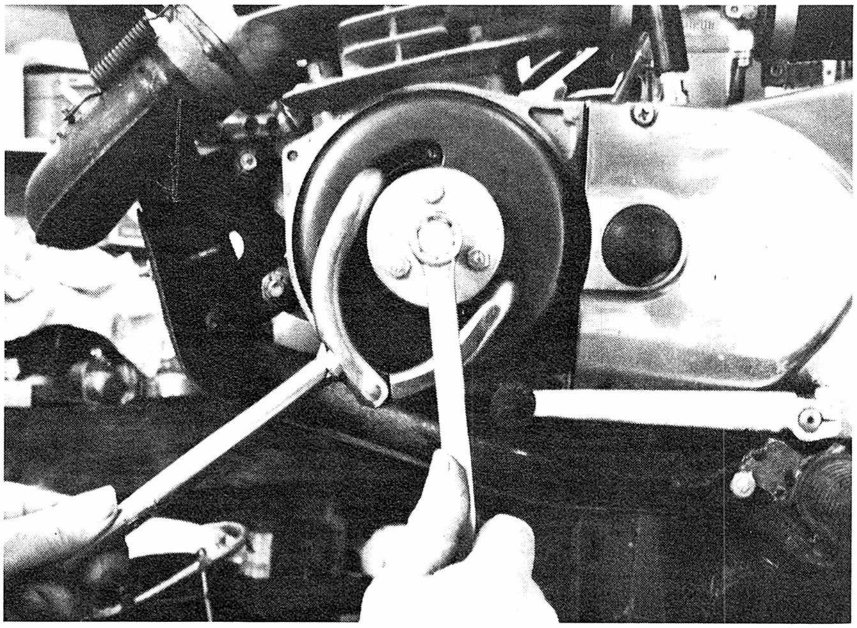
2. With the cover off, removal of the flywheel is the next task. Use a 17mm socket to remove the holding nut. The flywheel can be held with a strap wrench, this adjustable holder from Rocky Cycle (Sunnyvale, California) or you can order Suzuki's factory tool #09930-40111, rotor holder. The holder shown is more versatile and fits most standard magneto flywheels.

3. You will need to acquire the factory puller, shown, to break the flywheel free from the tapered crankshaft end. Suzuki part #09930-30711. Do not use any other type puller as it will permanently damage the delicate flywheel.

4. Screw the puller bolts deep into the flywheel threads. With a 17mm wrench turn the puller center bolt while using a holder to keep the flywheel from turning. Do not hit the outside of the flywheel as this can damage or de-magnetize the magnets.

5. If air is available blast any dust or dirt from the point and coil area. Re-surface the points with Flex-Stone or the like then clean them with a clean white business card. Twist the card back and forth until it will come out clean. Don't pull the card out. Check the condition of the wires and insulation. If corroded or cracked repair by soldering or replace.

6. As you go to slip the flywheel back on the shaft reach in the inspection hole and lift open the point guide. This will prevent the flywheel from breaking or benting it when driven home. Do not put on the holding nut. Rotate the flywheel until the points are at their widest opening. With a screwdriver set the gap at .015 inch.



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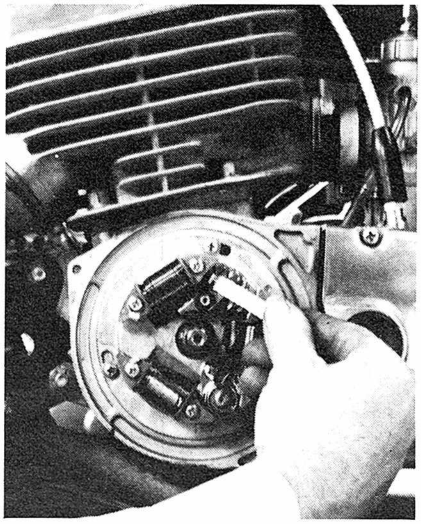

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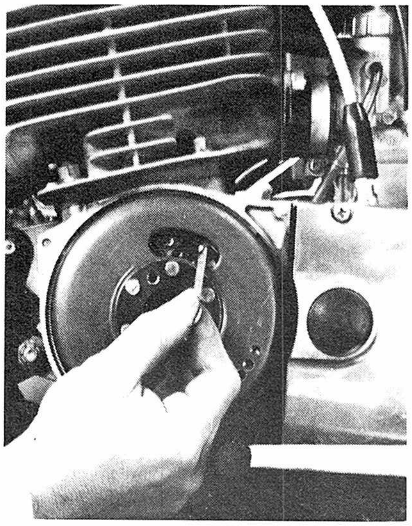

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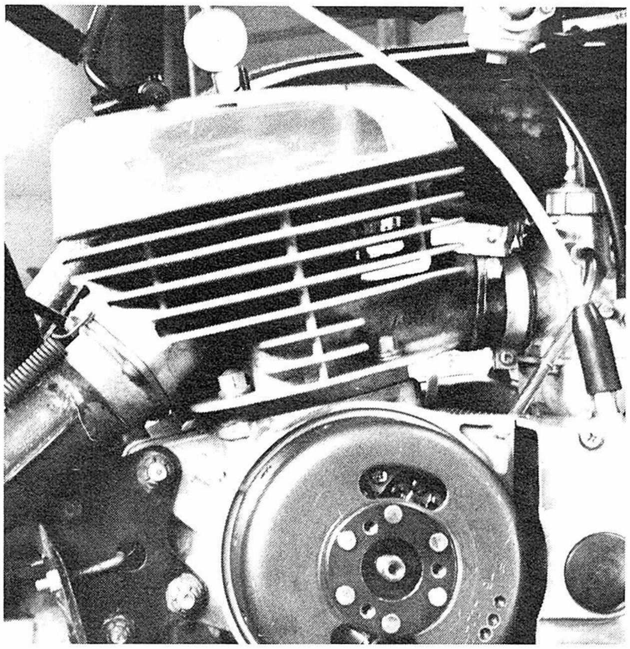

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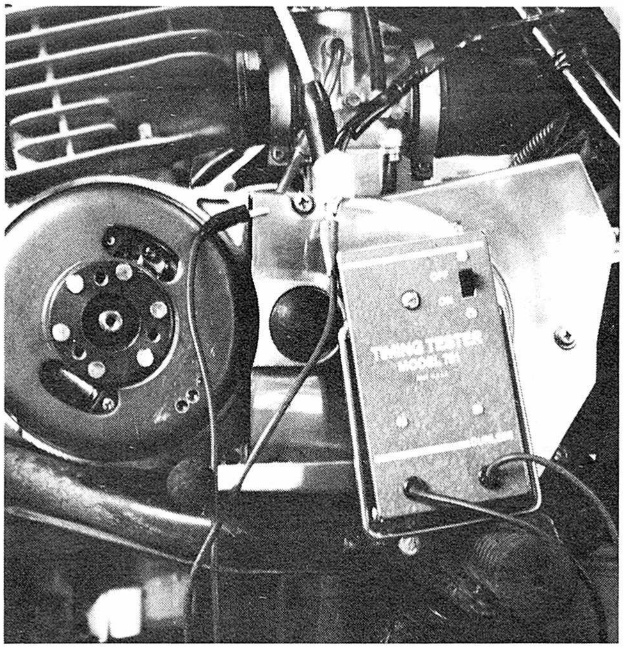

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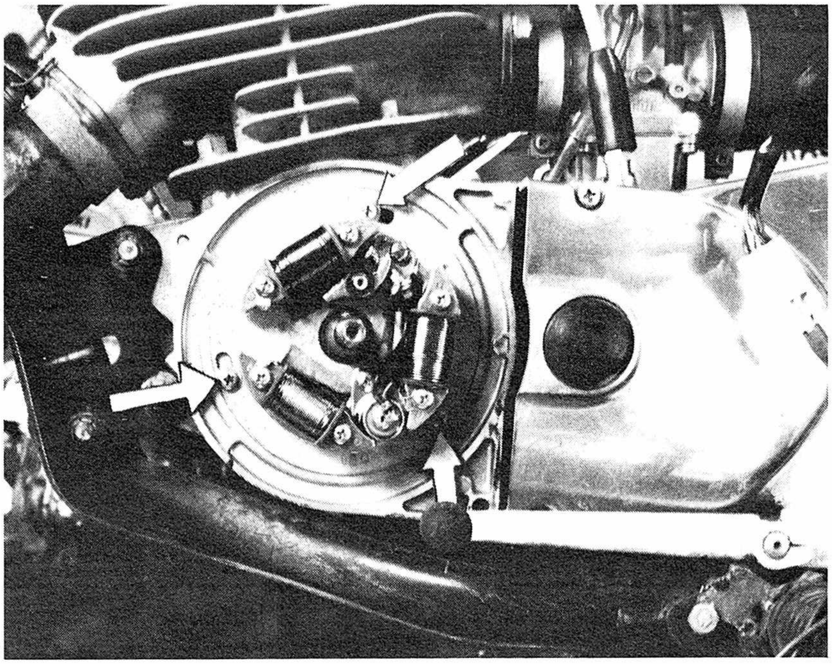
7. Remove the spark plug and install Suzuki's dial indicator. Can be ordered from your dealer, part #09931-00110. Rotate the flywheel until the piston drives the dial indicator up. Then spin the flywheel down and back up to top dead center. At TDC set the dial face to zero.

8. Disconnect the male/female plug in the wiring loom located under the seat. Take the two leads from the buzz box and connect one to ground and the other to the black and yellow color coded wire from the magneto. Rotate the flywheel from the bottom of the stroke up until the piston reaches 2.7mm Before Top Dead Center. At this point the buzz box tone should change.

9. If the buzz tone changes before or after the 2.7mm BTDC mark remove the flywheel and loosen the three phillips screws that hold the backing plate in place. With the screws loosened move the plate in the direction desired to retard or advance the timing spot.

10. Once you have the timing at the required 2.7mm BTDC spot replace the flywheel and tighten the holding nut. Also remove the dial indicator from the cylinder head and replace the spark plug. If you don't have availability to a dial indicator you can line up the timing marks located on the flywheel and crankcase. This will set timing at 2.64 mm, close enough.

11. To set the timing spot on without a dial indicator a timing light will insure proper line up of the marks when the engine is running. Although this is a time consuming project because the flywheel must be removed, backing plate moved and flywheel replaced each time the timing is set and changed. Be sure to tighten the holding nut before attempting to start and run the engine. Very slight movement of the timing (one to three tenths milimeter) can be accomplished by nudging the points with a screwdriver just enough to move them.



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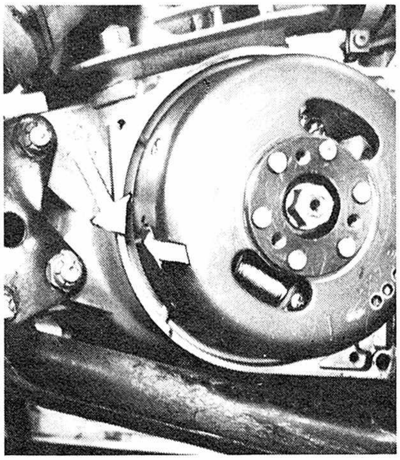

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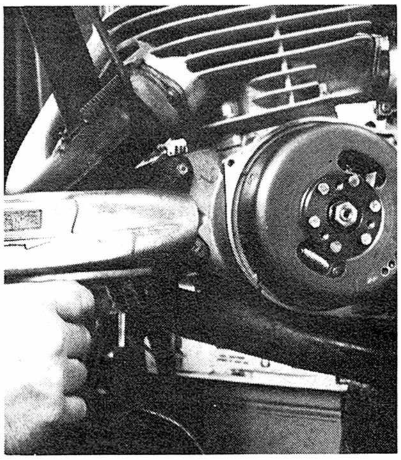

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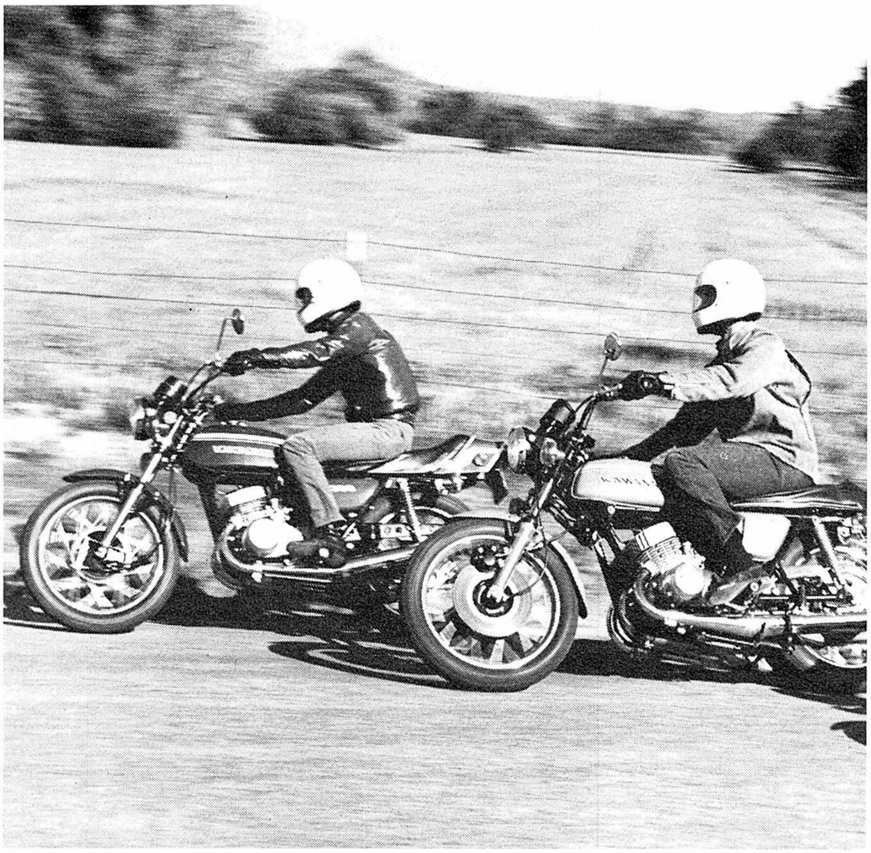
KAWASAKI 500cc MACH III

Except for ignition, the steps outlined here for the 500cc Mach III cover the 350 and 750cc three-cylinder models as well

The owner of a Kawasaki H-1 might easily be confused about his machine's ignition system. The 500 H-1 first debuted with a contact-type ignition, later switched to Capacitor Discharge and now has switched back again. With thousands of their CDI-equipped machines already on the road, with prompted Kawasaki to revert back to the conventional contact ignition is anybody's guess. Perhaps it was the CDI system's higher cost of manufacturing. Too bad, because the CDI is about the best ignition setup available.

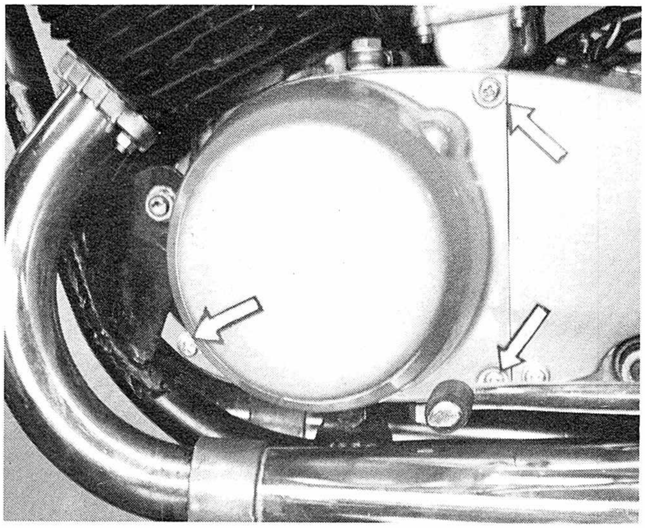


While CDI is a complicated system with more things that can go wrong, its advantages far outweigh the disadvantages. With CDI you can use a "surface-gap" spark plug. This is the coldest plug that can be manufactured, and use of same cuts chances of damage related to engine overheating. This also means that you can run the air-fuel mixture a little on the rich side and not have to worry about oil fouling a plug.

In theory, once you have set the timing of a CDI ignition, the system stays "dialed in" unless it is disturbed for some reason. To correctly time the CDI, a dial indicator should be used. If there's a scarcity of funds, rent or borrow one from a friend. The only other special tool needed is a timing light.

1. Remove all three spark plugs to crank engine easily. CDI sending unit is reached by removing three Phillips screws (arrows) in the front left-hand cover.

2. With cover removed, begin by checking clearances between the small black pick-up unit at the bottom and the three projections on the signal generator rotor. Turn the crank end until each of the projections lines up with the pick-up and measure the gaps with a feeler gage. Write each reading down so you don't forget. What you're after is the gap with least clearance, they may vary.



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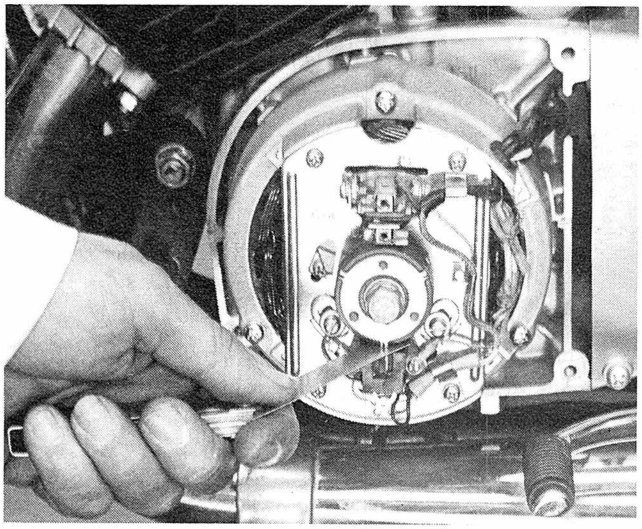

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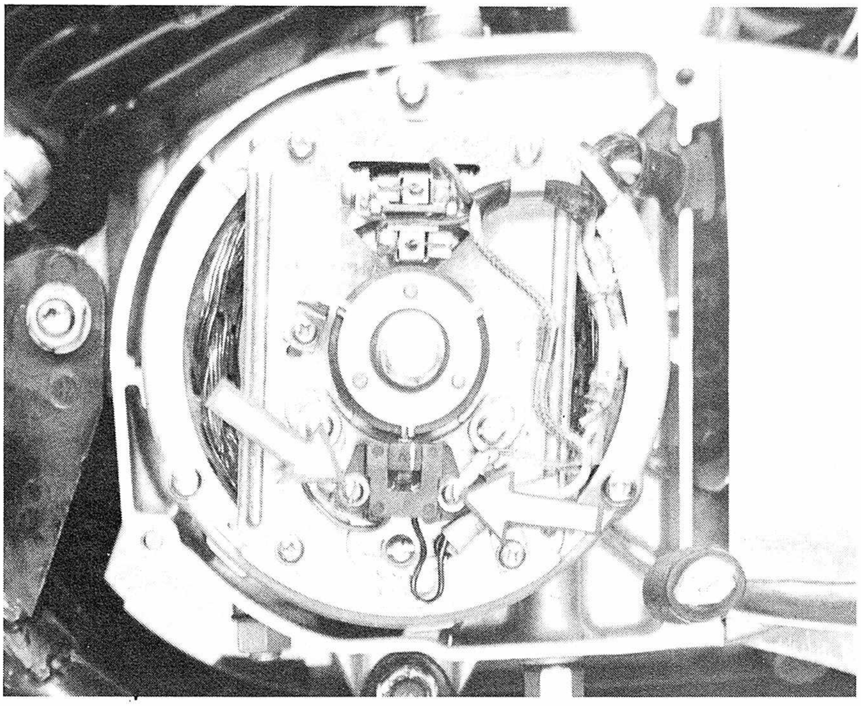

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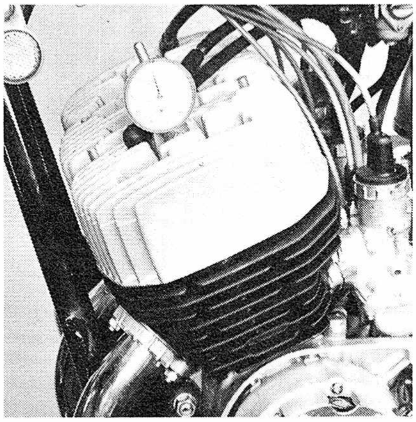
3. When you have found the smallest gap, set the projection over the pick-up and adjust the gap. Loosen the two screws (arrows) holding the pick-up and insert the feeler gage far enough to measure the projection at the back of the rotor. Set the gap at 0.4–0.6 mm (.015–.023 in.). The reason for setting the clearance on the closest projection is that the difference in projections may be enough to cause fouling if set on the widest.

4. Rotate the crank to bring the left hand piston near top center and install dial indicator. Rock the crank to determine exact Top Dead Center (TDC) and set dial face at zero. Rotate engine backwards to about 4 mm BEFORE TDC and then bring forward to 3.45 mm (.136 in. or 25 degrees) BTDC.

5. With piston correctly positioned, loosen three screws (arrows) securing pick-up backing plate. The plate may now be moved to adjust timing by wedging with a screwdriver as shown. Loosen the screws enough to allow the plate to just move.



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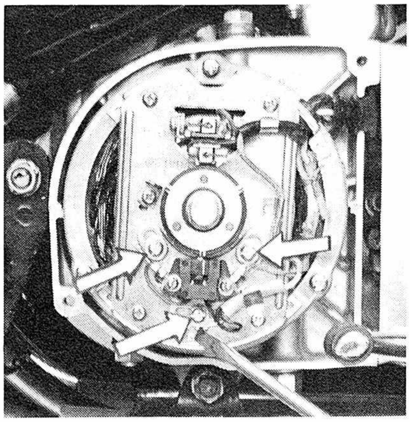

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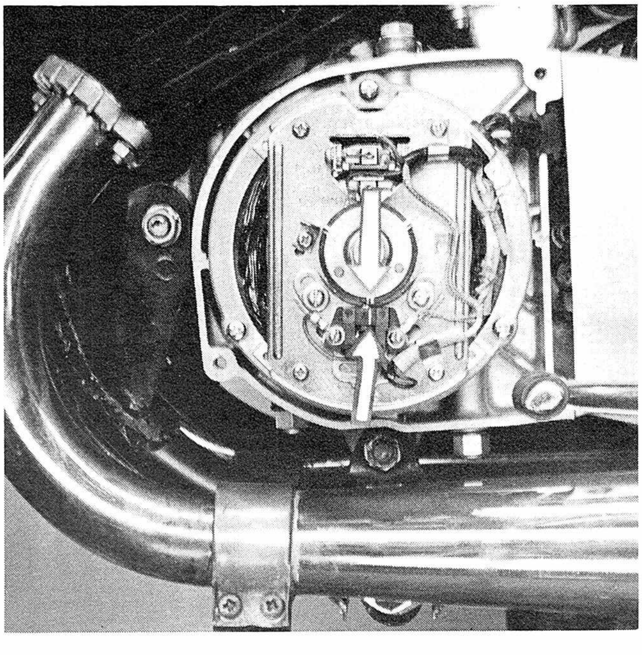
6. Move the plate until the pick-up line (bottom arrow) aligns with the mark on the rotor projection (top arrow). This will give the trigger impulse to the CDI sending unit at the correct time. However, it is important to still make a second check with a timing light.

7. With a needle-nose pliers, bend the pointer on the left hand side, as shown, until it aligns perfectly with the mark on the signal generator rotor (arrow). This must be done while the piston is still positioned at 3.45 mm BTDC. The purpose is to give you a reference point to check with the timing light. Now install a new set of surface gap spark plugs.



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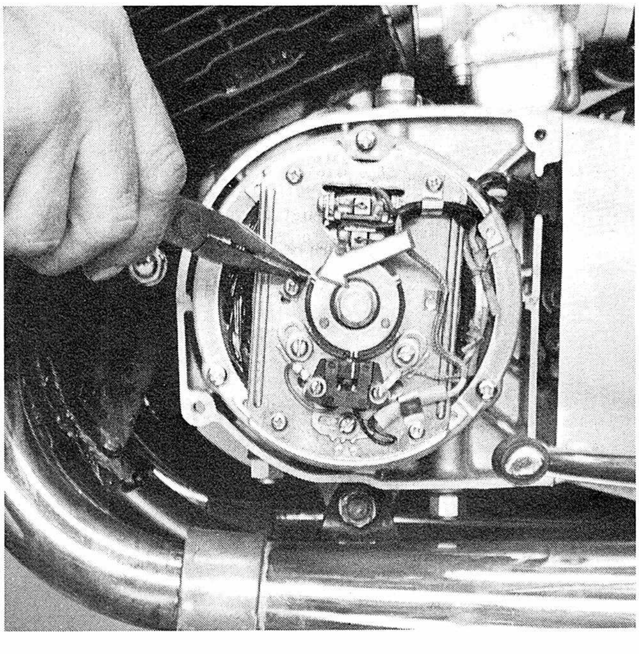

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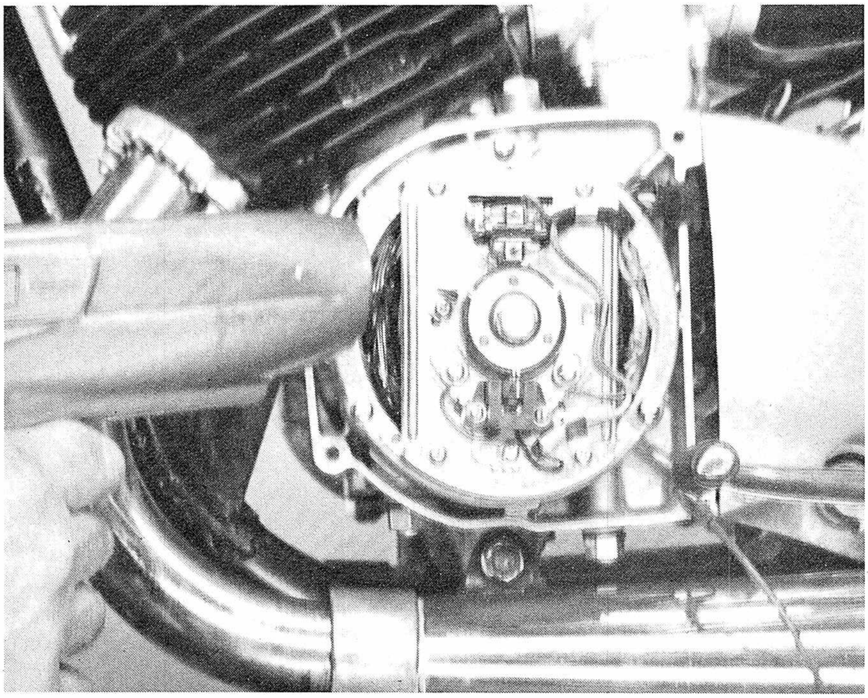
8. Hook up the timing light to a separate power source (do not use the battery on the machine). When using a battery powered timing light, always run a ground wire from the battery ground to the machine to protect the light from damage. Using the pointer as a reference, make the final adjustment on the pick-up backing plate so the mark on the signal generator rotor aligns with the reference pointer at 4000 RPM. You cannot use the pick-up mark with a timing light, as the rotor mark will always be aligned with it, regardless of piston position.

9. To get at the oil pump, remove distributor outer cover by taking out three Phillips screws (arrows). Cover cannot be completely removed because of tachometer cable, but it can be slid up and put to rest on top of the right hand cylinder.

10. Normally, oil pumps open at the same time the carburetor slides lift, but on the H-1 the pump is adjusted to start opening when the slides are up about one-eighth of an inch. To get this adjustment, it may be necessary to set the lock nut (arrow) at the opposite side of the cable stop. Late models should have a different cable.

11. Screw the idle air screws all the way down (lightly), and then back them out about 1¼ turns. This will do as a starting point. About a ¼ turn either way should be sufficient to give a good idle after engine warm-up.

12. Synchronizing carburetors is very important on a multi. Adjust the cable stops by twisting the throttle full open (engine off) and lifting on each cable shown. Play should be taken out with the adjuster on top of the carb. After adjusting all to zero play, fire the engine, adjust the idle, and you're ready to go.



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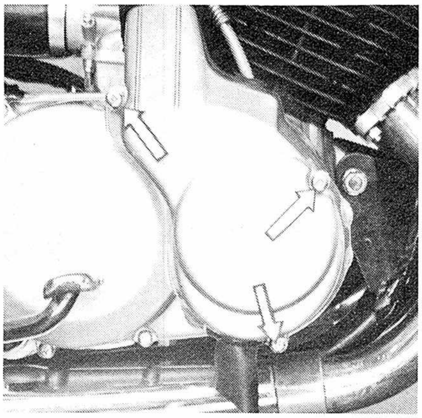

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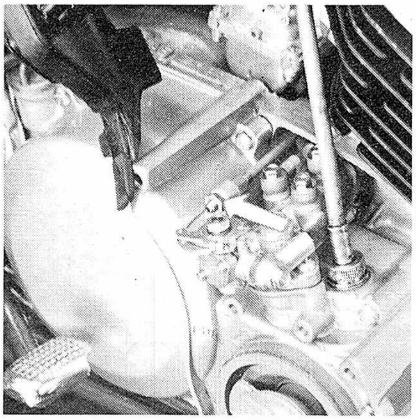

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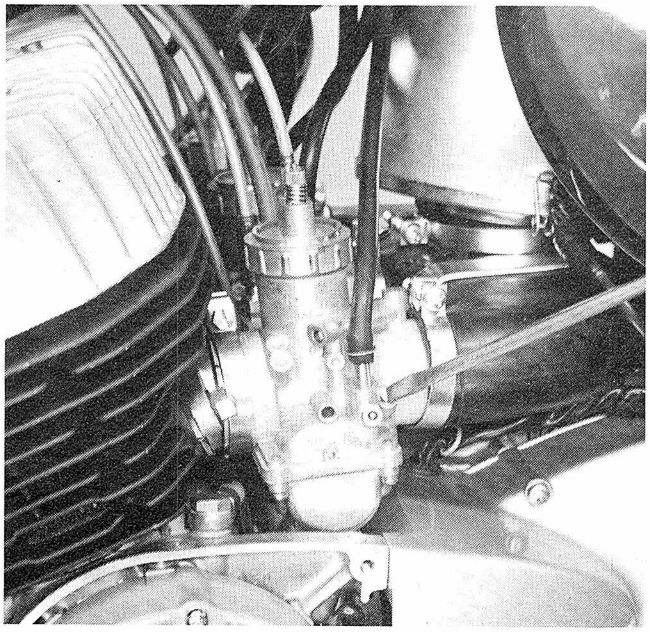

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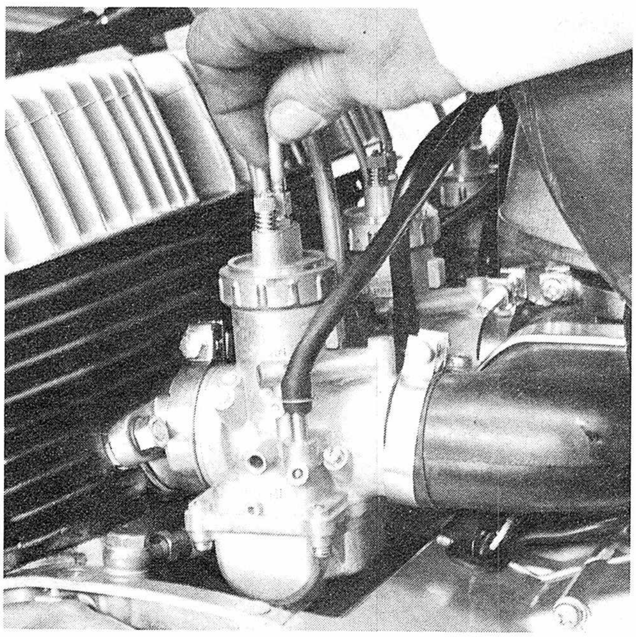

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MONTESA 175 & 250

Tuning principals are the same for all Montesa models up to the introduction of the CD ignition, but check specifications on your model

All Montesa models with flywheel magnetos have about the same timing procedures (excluding late models with CDI ignition), and pose no real problems for the careful neophyte. The important ingredients to tuning Montesas are the dial indicator and the buzz box. Before getting started, we'd like to pass along a few tips we acquired through constant contact with Montesa cycles.

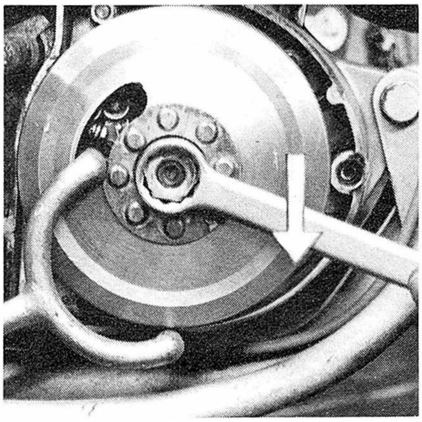
Always install new spark plugs. The type of riding you do will pretty well determine what heat range you select, but if there is any doubt always go one notch colder. Too hot a plug can cause serious engine damage, but if the plug is too cold, the worst that will happen is that it will foul. While on the subject of replacement, the air cleaners are a plastic mesh type that should be discarded and replaced with a foam element cleaner such as a Filtron type. The standard Amal carburetor settings are about the same for the Spanish and English versions. The idle air screw should be run to the bottom and backed out 1½ turns. When the engine has warmed up, you will probably have to lean it out a little—just set it where the engine runs smoothest.

1. Montesa hides their flywheel magneto inside the right side case cover. First obstruction to be taken off is the kick arm. Scribe a locating mark on the kick shaft before removing to insure replacing at correct angle. Also keeps the return spring tension the same. Completely remove bolt.

2. The shift arm will also have to be removed. Use a large screwdriver to take out the slotted screw holding the case cover in place. If it's stuck in place tapping the screwdriver with a mallet should break it loose.

3. Note that the flywheel holding nut is LEFT HAND THREAD. Remove the nut with a 22mm wrench. If you don't have a hard-to-get flywheel holder as shown or a strap wrench you can apply the rear brake and use the primary drive to keep it from turning. Don't try to jam a piece of metal or long tool in the inspection hole opening to keep the flywheel from turning. It will ruin the magneto.

4. The only tool to use to remove the flywheel is the factory puller. DO NOT attempt to use a gear or claw puller as you will ruin the soft brass flywheel. Some of the Montesa flywheels seem to become welded on the shaft. Don't pound on the wheel, but take it to your local dealer if necessary. Lightly dressing the tapered crankshaft with fine emery before re-installing the flywheel will ease its removal the next time you take it off.



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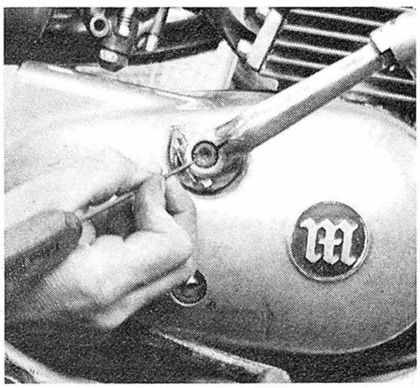

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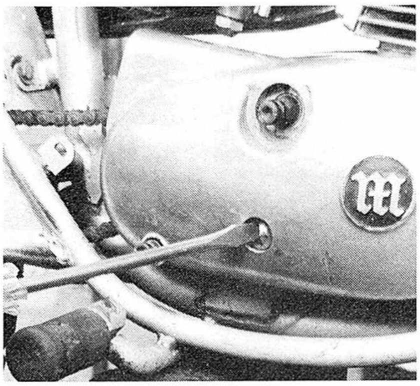

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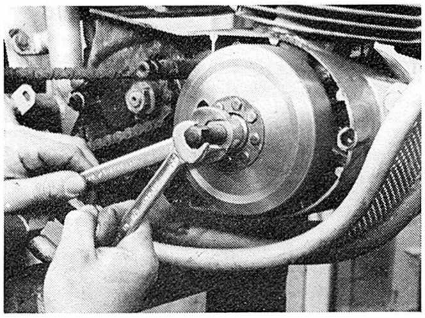

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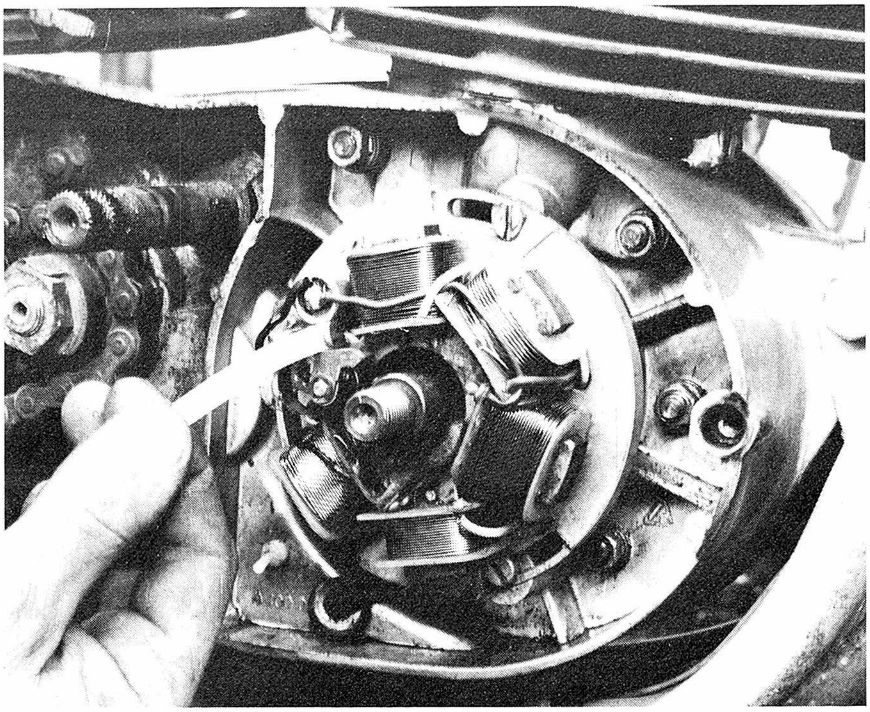

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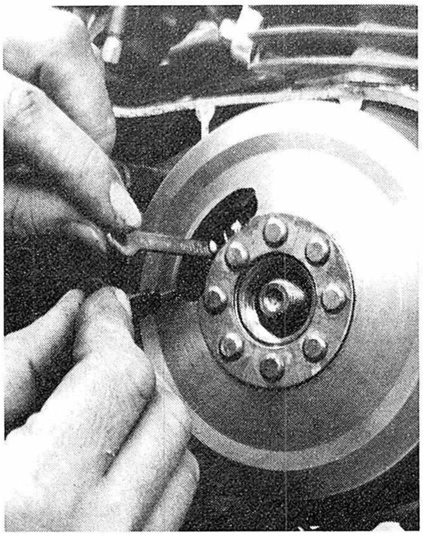

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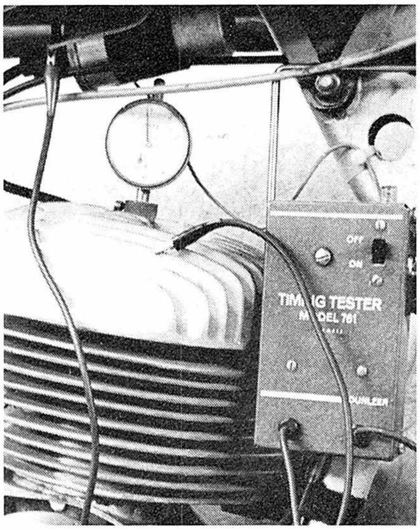

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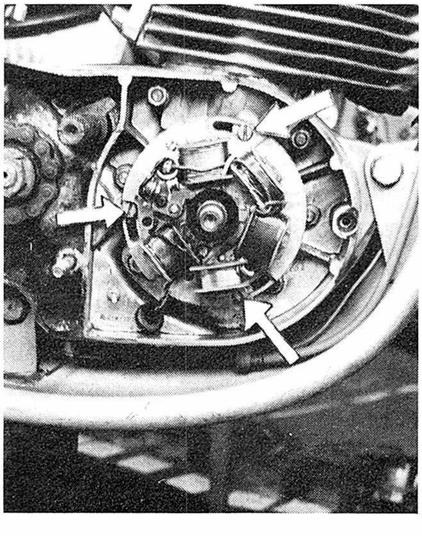

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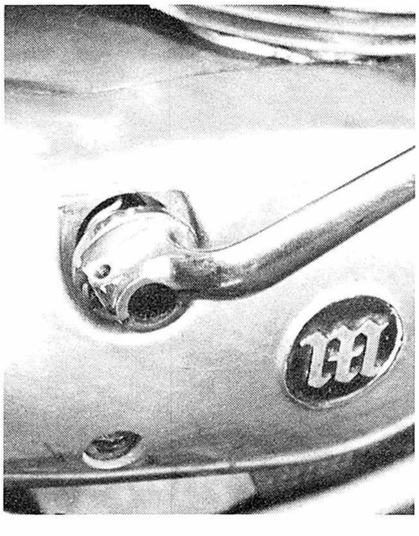

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5. Inspect the condition of points for pitting or excess wear. If badly pitted replace both points and condensor. If the points are only dirty clean with Flex-Stone then remove oil or grease build-up by inserting a clean white business card. Twist the card, don't pull in and out, until it comes out clean. Look for any traces of fuel leakage into cavity indicating seal leak. Excess amount of dust or dirt indicates case leak.

6. Be sure the woodruff key is in place and slip the flywheel back on the shaft carefully. Lift the point guide up out of the way of flywheel cam to prevent its becoming damaged. With a plastic mallet tap flywheel lightly in place. Do not replace the locking nut yet. Go through the inspection hole and loosen the point holding screw. Set them at .013 to .015 inch. They can be moved easily.

7. Remove the spark plug and install a dial indicator. Run the piston to top dead center and when the indicator is topped zero the dial face. Attach the buzz box leads to the magneto side of the coil and ground. Rotate the flywheel so the piston comes to bottom then turn in a forward direction until the dial indicator reads; 3.5mm for the 175 Sport, Enduro; 3.0–3.5mm for the 175 Cross or 5.5–6.5mm for 250's.

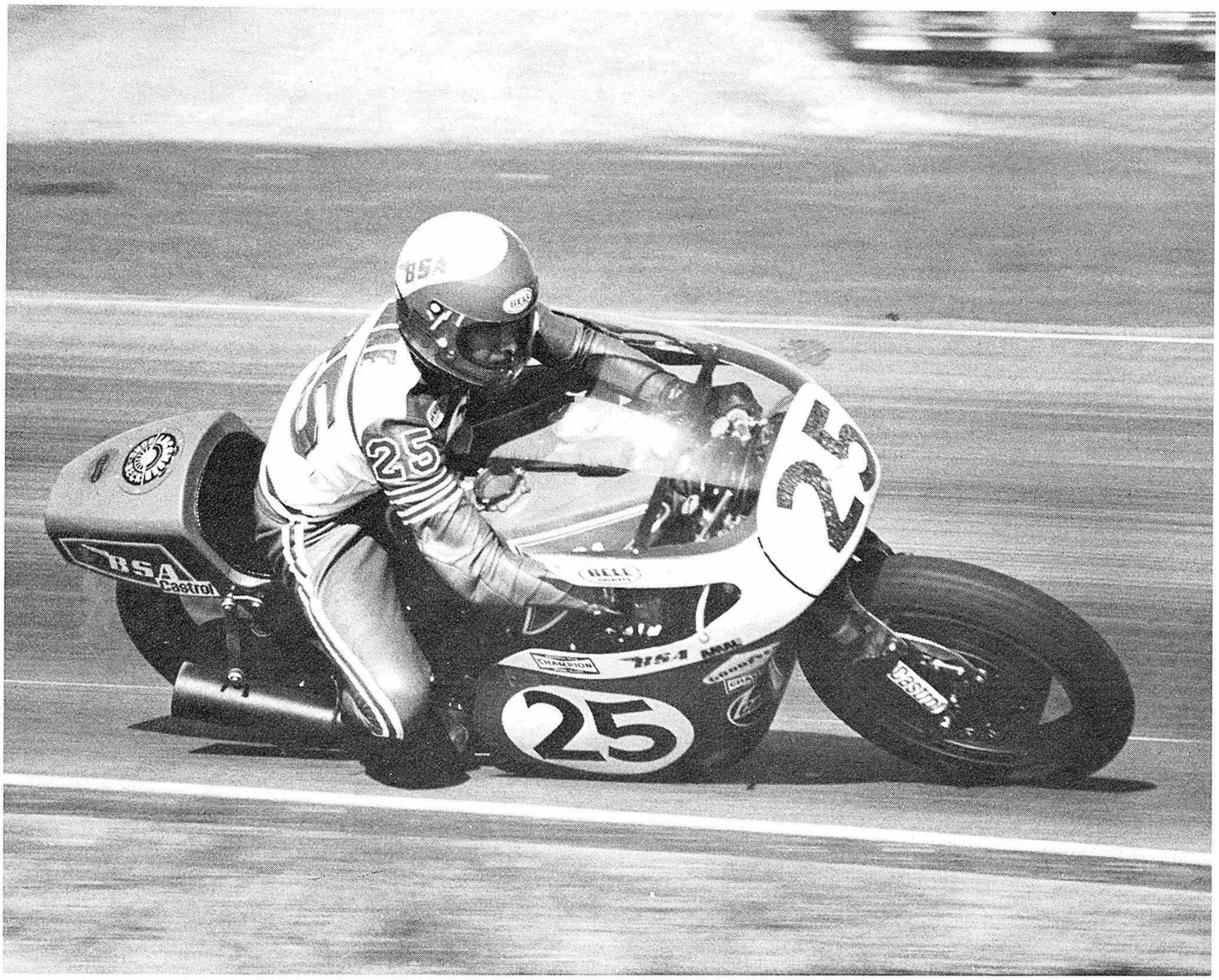
8. If buzz box tone doesn't change at the prescribed setting, turn it forward or retard until it does, to determine the direction the points must be moved to zero them in. Slight changes can be made by moving the gap.

9. If the timing is off considerably the flywheel must be taken off again and the backing plate moved. Loosen the three holding screws to move the plate. Check timing after resetting.

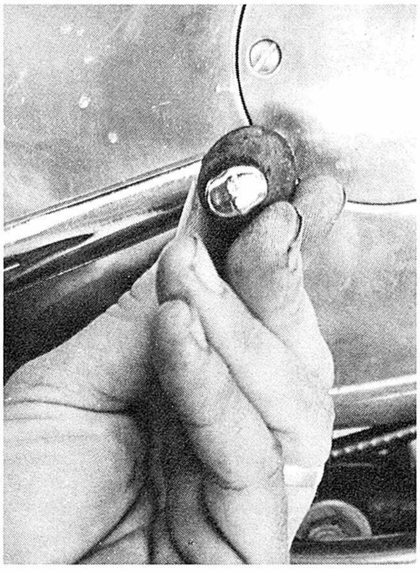
10. With the flywheel in place tighten down the locking nut to factory torque specs. Remove the dial indicator and replace the spark plug. Seal the case cover and replace it along with the shift shaft. The kick arm may now be replaced to its original position using the scribe mark on the kick shaft.

BSA 650

The 500 and 650cc unit-constructed twins follow the same basic tuning format



BSA was one of the first to do something to help mechanics when they introduced the "stop-plug" method of timing their unit-construction A-50 and A-65 ohv vertical four-stroke twin models. This was a little better than earlier models, but there was still the problem of adjusting the backing plate to time one side, then adjusting the point gap on the other side. Lucas has now moved the condensers out of the point area and installed contacts that are individually adjustable for timing. They have also provided timing marks on the alternator rotor to allow the timing to be checked with a strobe light. This has cut the need for special tools down to a minimum and makes tuning easier.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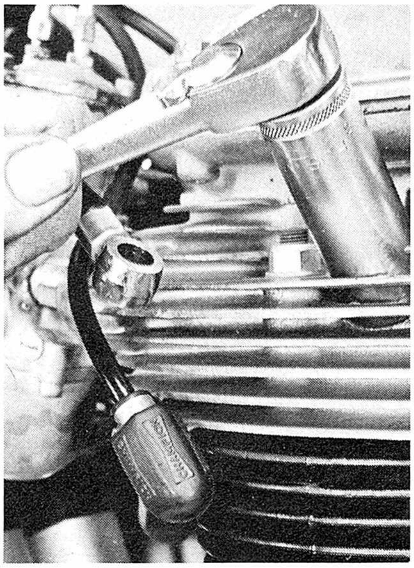
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1. The engine must be turned over to get the pistons in proper position. The best way to permit rotating the engine while tuning is to place the transmission in top gear after the machine has been set on center stand. With the rear wheel off the ground, engine may be turned over by spinning the back tire.

2. To further ease spinning engine, remove spark plugs. Set them aside for spares and plan on replacing with new ones. This also permits visual inspection for piston location when turning the engine over.

3. To ease access to rocker assembly it's best to remove the gas tank. Take off the rocker cover retaining nuts and remove aluminum casting. When replacing be sure to torque down to factory specs. Overtightening will warp alloy cover and lead to oil leaking. Also use good sealant.

4. With the valve cover removed it's time to rotate engine to proper position by turning the rear wheel. In top gear, the engine should spin over very slowly while turning the rear wheel. Turn rear wheel until the right side intake valve is full open, on top of the cam lobe ramp. Now go to left cylinder and adjust the intake rocker clearance. While on the left side turn the rear wheel until intake valve is open, then adjust same on the right cylinder. Set the exhaust valves in the same manner, adjust left side with right side valve open and vice versa. Settings with a dead cold engine are: intake .008 inch; exhaust .010 inch. It's always a good idea to replace old gaskets with new ones if possible.


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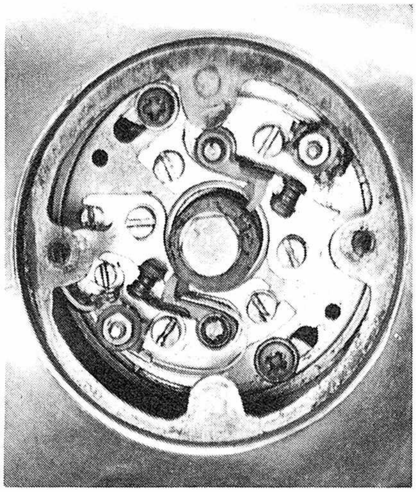
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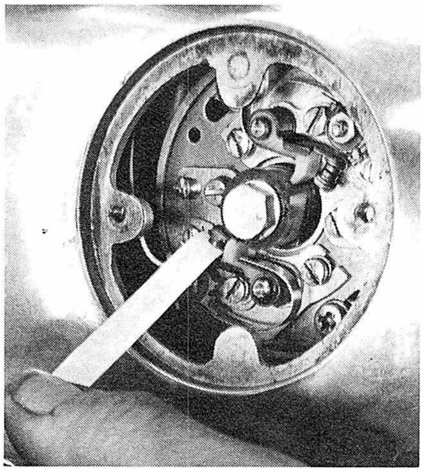
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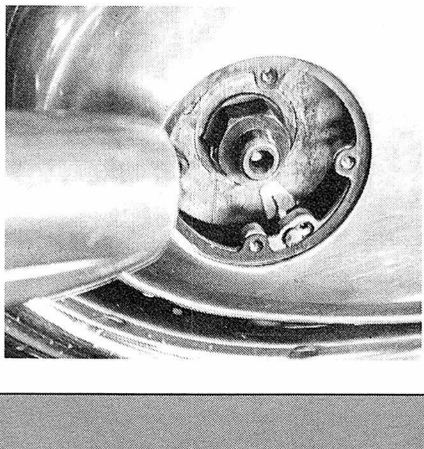
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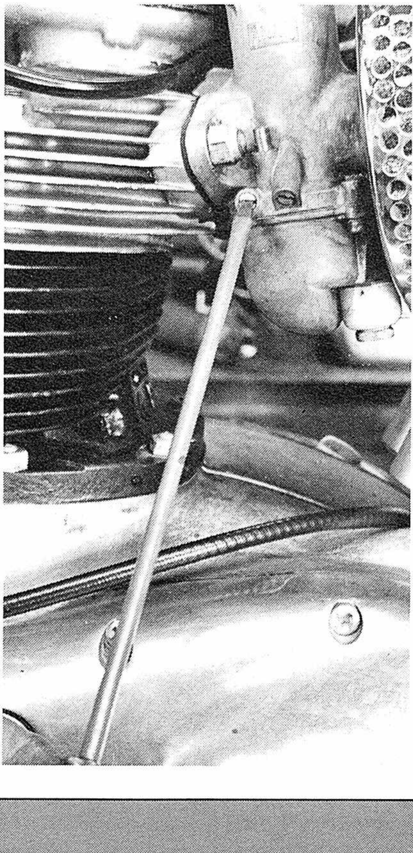
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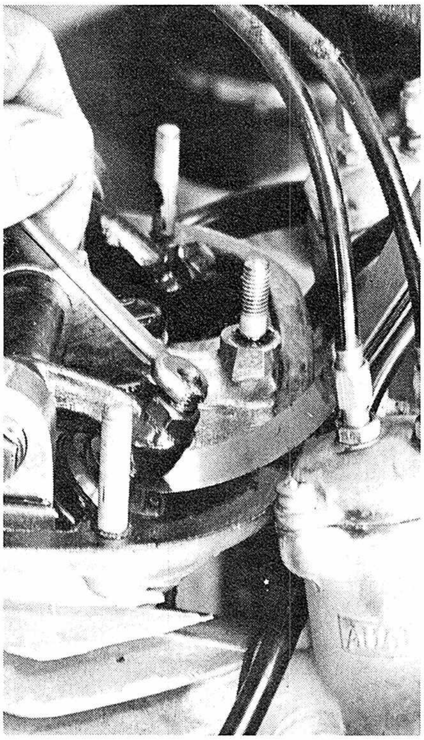
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5. Take off point cover by removing two holding screws. Inspect nylon point guides for excessive wear or even breakage. It's not uncommon to have the guides break off and cause one of the cylinders to refuse to run in tune with the other. At this point also check condition of the adjusting and holding screws and nut heads for rounding. Some shadetree mechanics often damage this hardware making it impossible to get everything tightened down properly. If you have air, blow out dust and dirt.

6. Open the points and inspect for severe pitting caused from age or arcing from a bad condensor. If beyond resurfacing replace both points and condensors. Otherwise insert a piece of Flex-Stone and smooth surface. Now place a clean white business card between the contacts and twist back and forth. Remove when card comes out clean. Don't pull out. Place a small dab of oil on cam and adjust points opening to .015 inch.

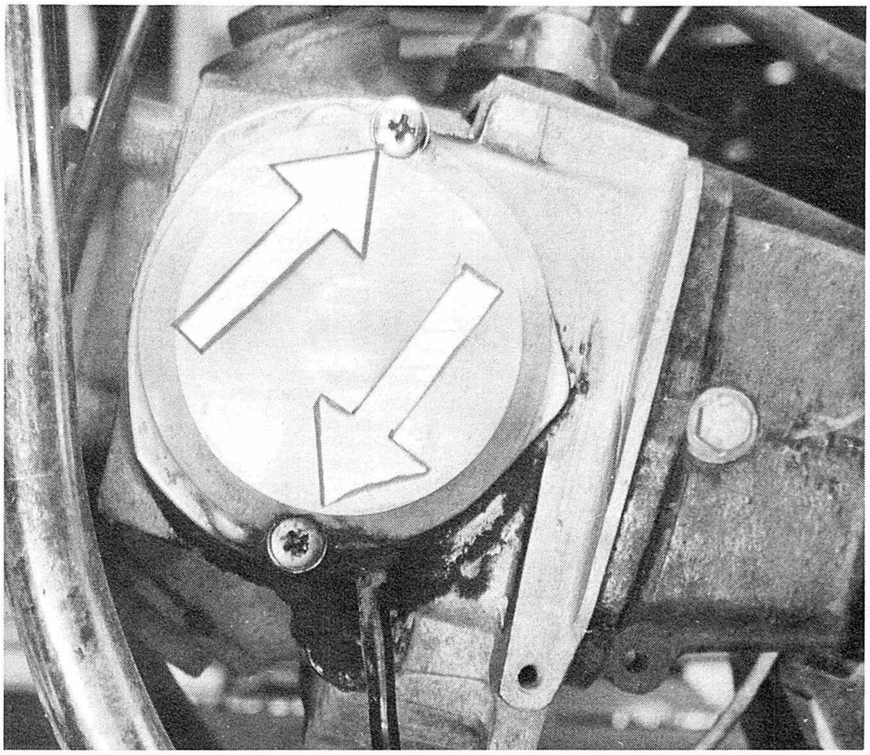
7. Remove inspection cover on the left side case. Inside you will see alternator rotor as well as a small pointer on lower side of the opening. On the surface of rotor is a timing index mark that you will use to align with the pointer. Note that alignment of these two marks is to be done with the timing at *FULL ADVANCE.* Now attach an automotive strobe light to one of the spark plug leads. Start the engine and rev up enough (over 2,000 rpm) to open advance full. The pointer and timing mark should line up. If not adjust the points of the cylinder your testing to match. Repeat the process with other cylinder, replace cover.

8. With timing set, adjusting the idle is next. Using a long thin screwdriver, turn idle screw to bottom. Back it out 1½ turns, then adjust.

HONDA 90

This tune-up procedure will cover all "S-90" type overhead cam engines and supply the basics for Honda's other ohc singles. If your engine number begins with C-200, this isn't for you

If Honda was to glorify one of its machines as *the* unsung hero, it would have to be the Trail 90. This little work-horse of the Honda line is amazingly popular, yet its exploits are seldom publicized. It wins no races, it sets no records, but it does keep thousands of hunters and weekend trail riders happy with its bullet-proof engine performance. As most of this machine's running is done in the fair-weather months and in the lower gears, it gets more than its share of abuse. For this reason, the 90 should probably be checked more often than a street machine. A tune-up on the 90 is simple and the only special tools needed will be valve adjustment wrenches (which come in the tool kit) and an automotive-type timing light. Before you begin, one thing to keep in mind is that this machine has a battery ignition and therefore (unless you enjoy shovelling sand against the tide) the battery must have a full charge.



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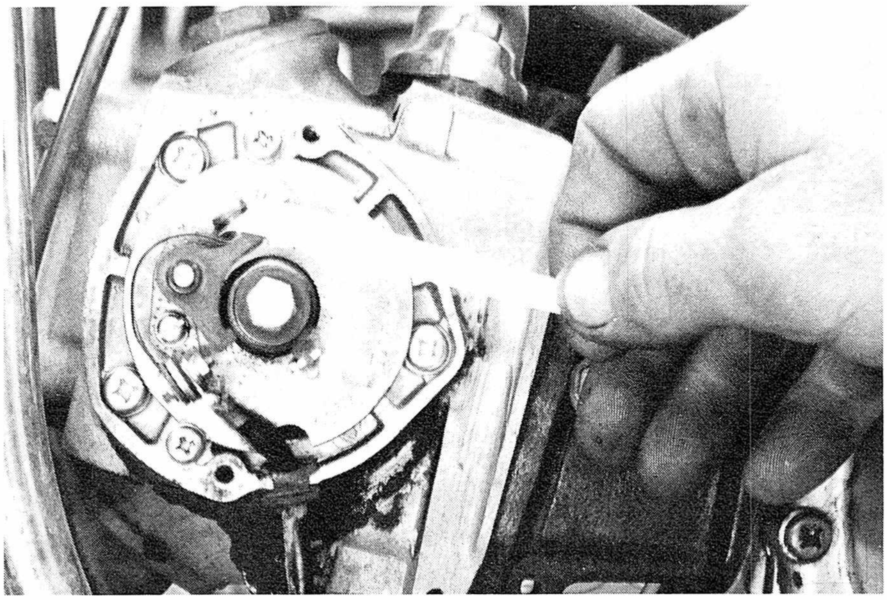
1. Start by removing spark plug to eliminate compression restriction. Plan on installing a new spark plug for insurance. The point cover on the left side of cylinder head is removed after taking out the two phillips screws holding it on. The points ride on end of overhead camshaft. Upon replacing the cover be sure gasket is included.

2. Clean point area with compressed air or a good cleaner like Contact Clean in spray can. Make sure there are no oil or dust leaks. Inspect contact areas of points. If severely pitted replace them and condensor. Otherwise clean them with Flex-Stone. Then insert a clean white business card and twist back and forth until dirt is gone. Once resurfaced and clean set the points at .014-.016 inch.

3. Still on the left side of engine is alternator cover. Take out the three holding screws and remove the cover. When the cover is taken off some oil may leak out. This is normal. Now the stator and rotor are exposed.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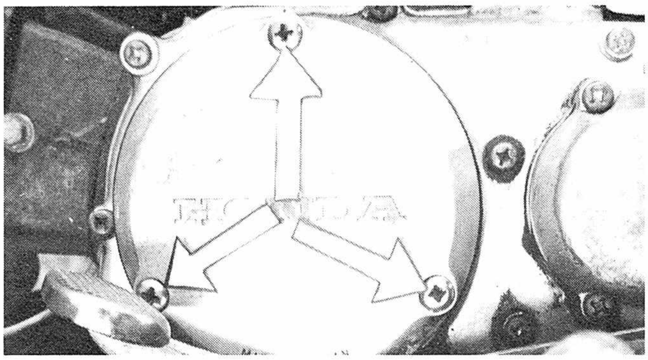
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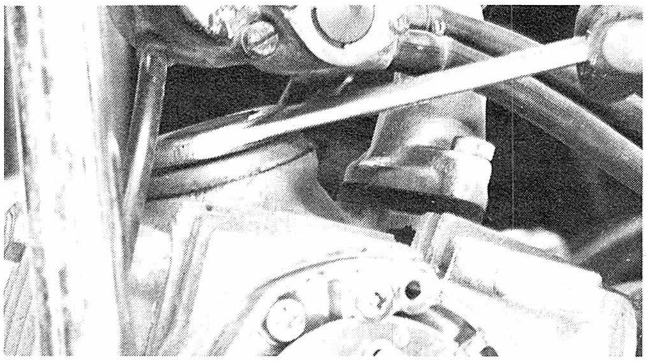
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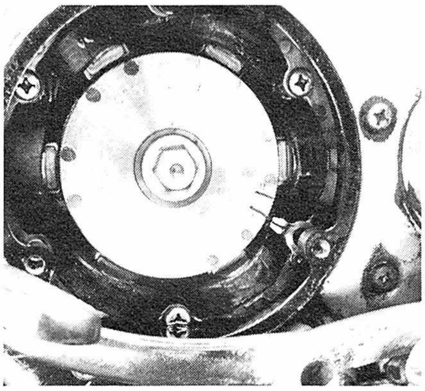
4. The Honda tool kit comes with a special box-type wrench to remove the tappet inspection caps. If not available a 23mm wrench will do. The top cap is an inspection hole for the intake valve while the bottom is for the exhaust. Upon replacing them screw in carefully so as not to damage threads. A dab of grease aids seal.

5. Go back to the alternator and turn the 14mm rotor retaining nut with a wrench to rotate the engine. Line up the 'T' (Top Dead Center) mark on rotor with the stationary pointer on stator as shown. This must be done on the compression stroke. As you rotate engine forward, these marks will line up after intake closes.

6. The trail models will have a skid plate attached that gets in the way of exhaust valve adjustment. Fortunately there is a hole in the plate that permits access. Honda's special tool should be in the bike's tool kit. The recommended settings are: .002 inch for the intake valve and .004 for exhaust with the engine cold.

7. Connect the leads of your buzz box to the ignition wires. Turn the engine over by rotating the rotor bolt with a wrench. As the points open the buzz tone will change and should align with the 'F' (Fire) line.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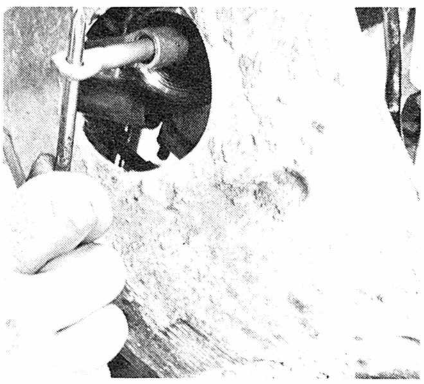
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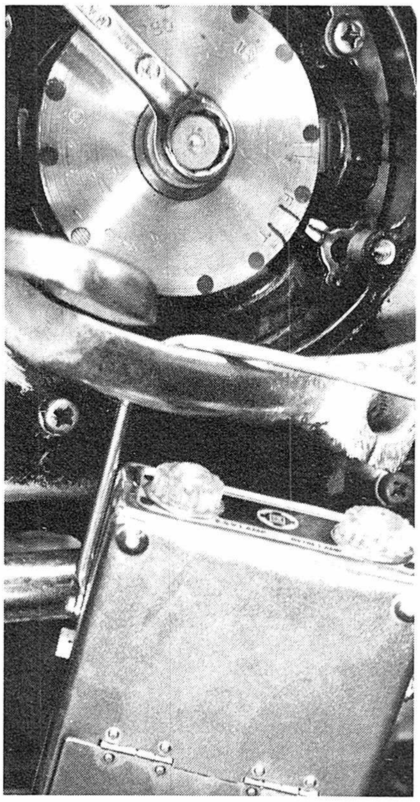
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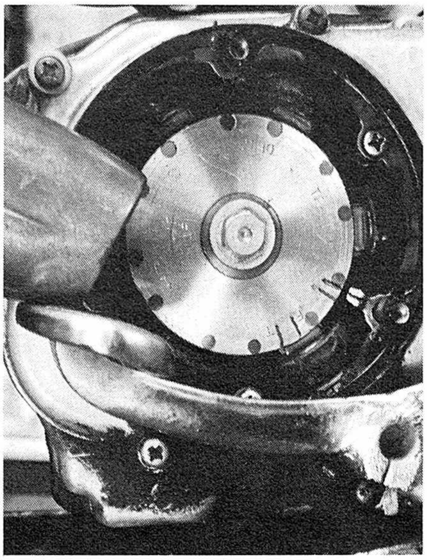
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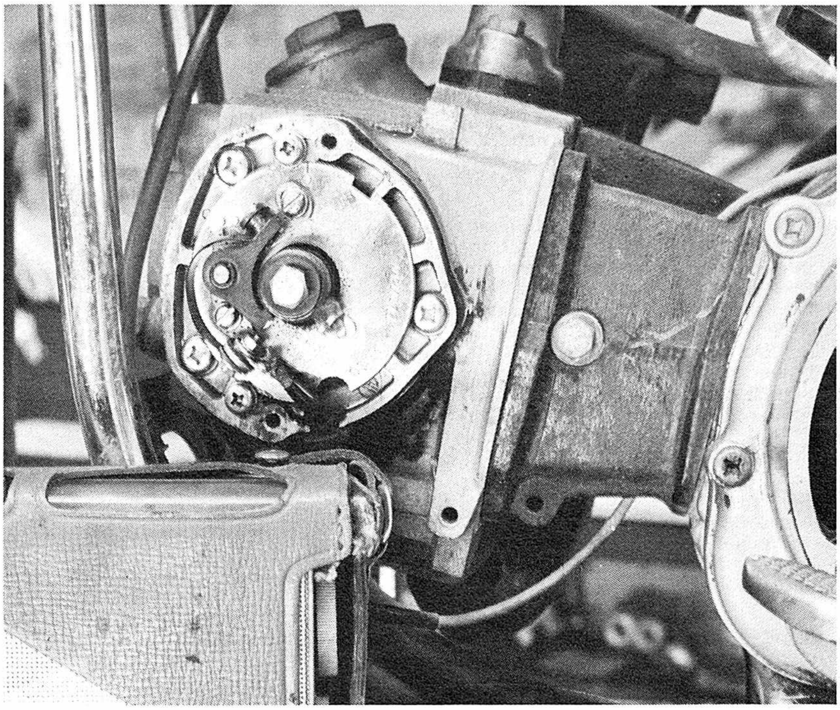
8. Ideally you should check the timing location with an automotive strobe light in addition to the buzz box. This permits you to check advance unit's operation. Attach the timing light to the spark plug. At an idle, the light should line up the 'F' mark with the pointer. Then rev the engine and the timing marks should line up as shown. These two checks run simultaneously should show advance unit to be operating right. Moving point plate will zero in the marks.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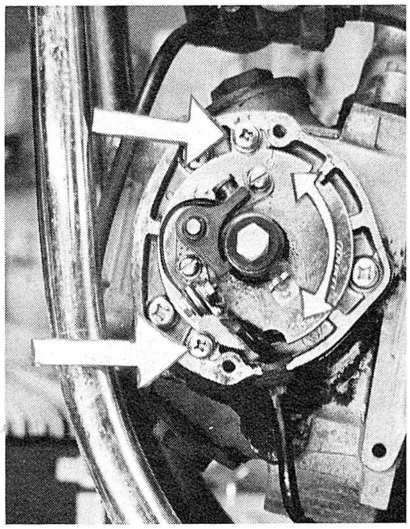
9. One trick method of timing is the "poor man's" way which works well in the field with the use of a transistor radio. Set selector knob in a place where there are no broadcasting stations and turn the sound full on. Loosen the backing plate screws as shown and close the points. Now turn on the ignition key and slowly rotate the engine forward. Just as points open there will be a loud crack in the radio sound volume. This should occur just as the 'F' mark aligns with the pointer. The point plate may be moved to acquire alignment. This method may be used on any machine with a battery ignition to set the timing.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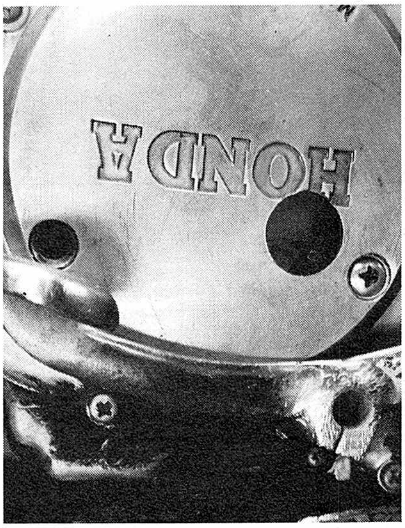
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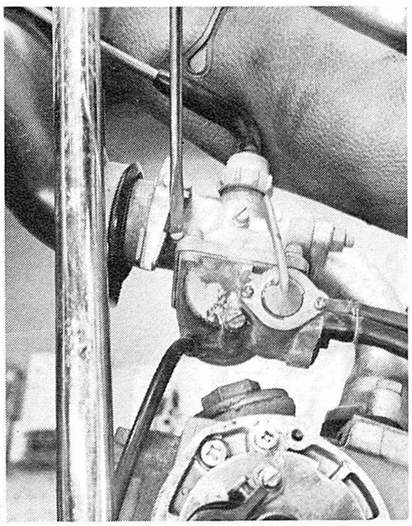
10. While rotating the backing plate experiment with it a few times to find out which direction you will need to turn it to zero in the timing. Check condition of wires and insulators.

11. Because of the oil splash, timing with a strobe light can become rather messy. To arrest the oil spray problem an old cover plate can be used as a splash guard by drilling a hole in it at the pointer location and placing it over the cavity while the engine is running. Does the trick.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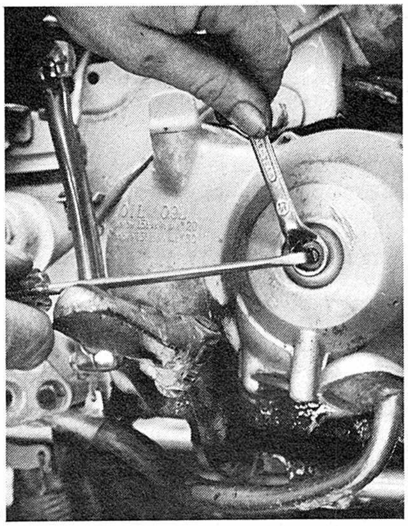
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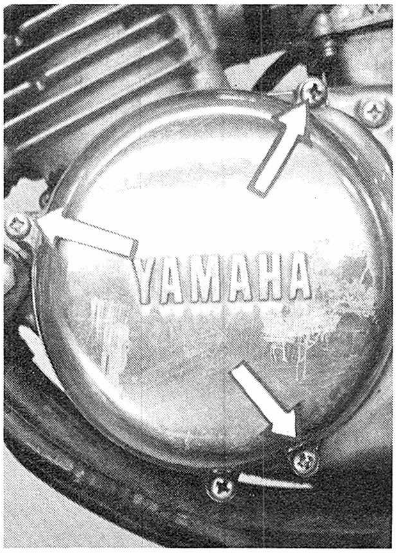
12. Now set the idle air screw with a screwdriver. Run the screw to bottom, then back out 1½ turns. Turn the screw in or out until idle smooths.

13. Check the clutch adjustment before you quit. Loosen the lock nut on the right side with a 10mm wrench. Back out the center adjusting screw slowly until resistance is felt. Turn it in about ¼ turn, hold in position and tighten lock nut.

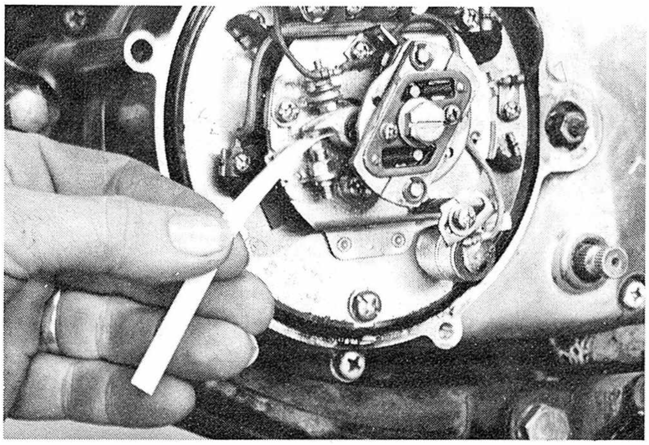
YAMAHA AT-1

The "different" one in Yamaha's line incorporates a starter/dyno system. This is used on all their electric-starter models

The Yamaha AT-1 Enduro uses a starter-dynamo rather than a fly-wheel magneto. But don't let this throw you, actually it's an easier system to work with. The contact points are right there where you can get at them, and that's half the battle. To make up for the shortcoming of the head having to be removed before a dial indicator can be installed (this due to the angle of the spark plug hole), the AT-1's designers thoughtfully provide timing marks to use. But be aware that one of these marks is movable and you have to verify that it is positioned right. Therefore, the position of the pointers must be checked the *first time* with a dial indicator, then locked down and never again disturbed. This does require the removal of the head and refitting with a torque wrench. It is advisable to have this done at a reputable shop. Once this zeroing-in is out of the way, you can forever check and adjust the timing yourself with the knowledge that the marks are right. If you don't have a "buzz box" to check the timing with, substitute a small light bulb hooked to the contacts—make sure the key is on.



1. To acquire access to the starter/generator the dyno cover must be removed. Take off the shift lever by removing the pinch bolt with 10mm wrench. Now unscrew the three phillips screws and the cover should come off with a tap from a plastic mallet.



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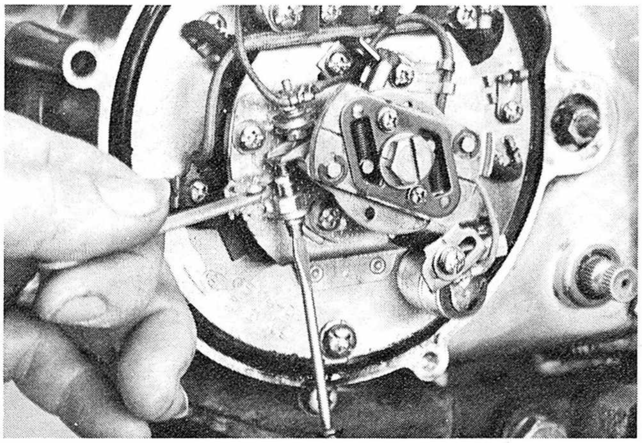

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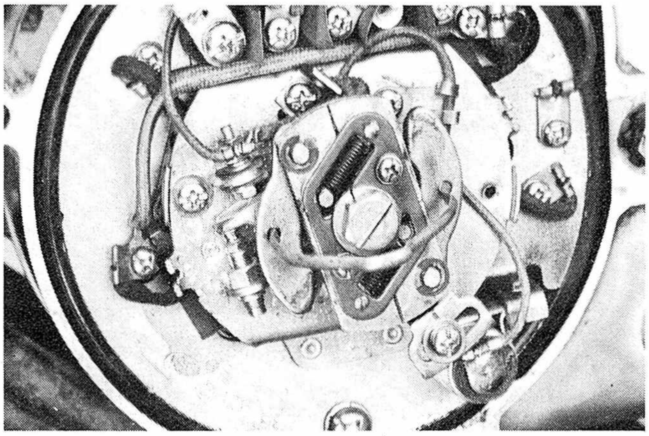

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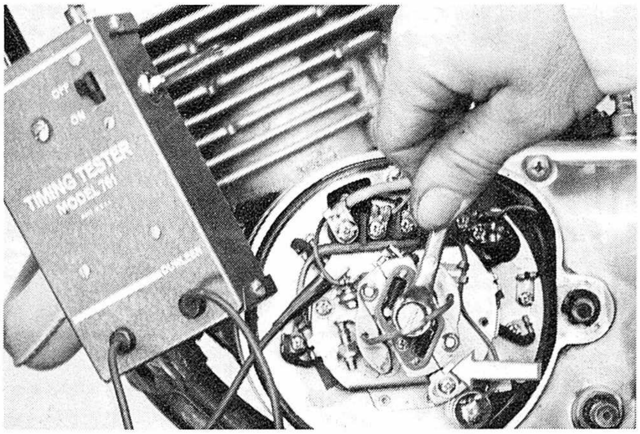

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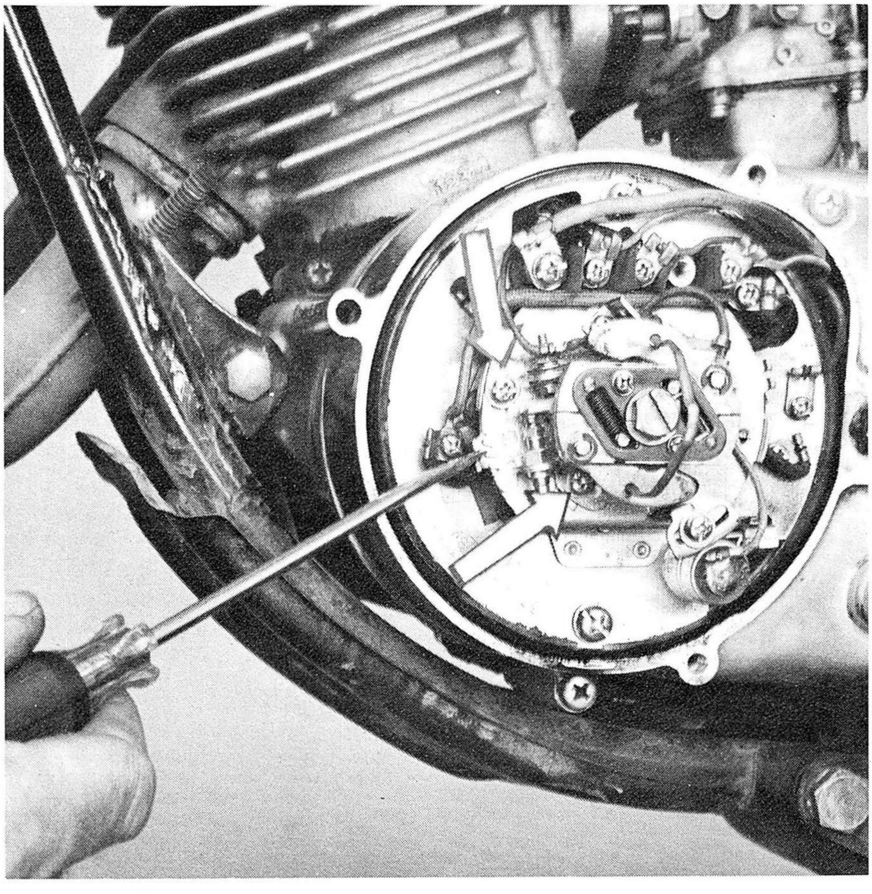
2. Make sure the point area is clean. Use compressed air or contact clean to remove dust and dirt. Check the condition of the contact surfaces. If badly pitted replace both points and condensor. Otherwise resurface with a piece of Flex-Stone. Now insert a clean white business card and twist back and forth until grime is gone.

3. Rotate the engine by turning the timing advance locking bolt until the points are at their widest opening. Now set the gap at .014-.016 inch. After tightening the lock nut check the gap again as it may move.

4. The timing must be set with the centrifugal advance full open. To hold centrifugal weights open, a spring clip can be jerryrigged from a piece of coat hanger wire or the like. Be sure both weights are full open.

5. Connect the buzz leads to the point connections. Turn advance holding bolt until line of the centrifugal weight plate aligns with line of pointer. At this point the tone of buzz should change indicating the opening of points. If not, hold advance in place.

6. If the timing isn't spot on, loosen the two locking screws and move point plate until the buzzing changes. Moving the point plate can be done by levering the notched side of point plate as shown. Once set with lock screws tight, re-check timing. Also check condition of wiring.



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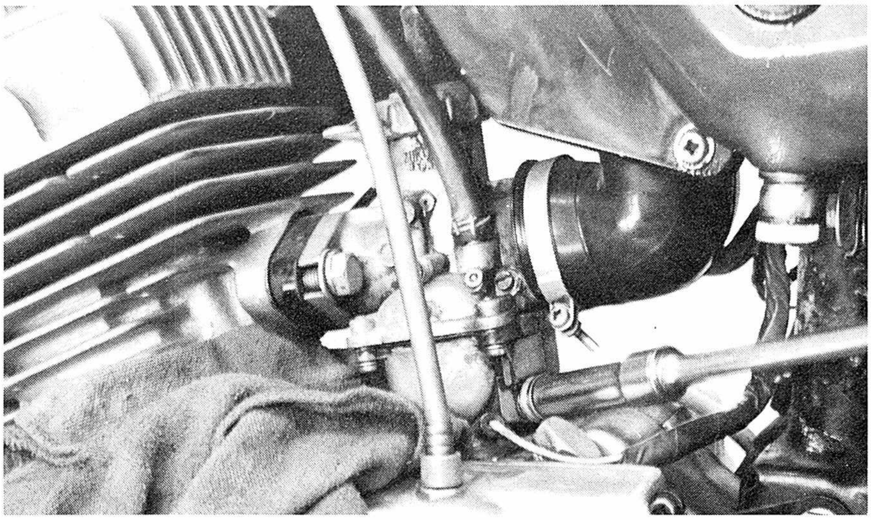

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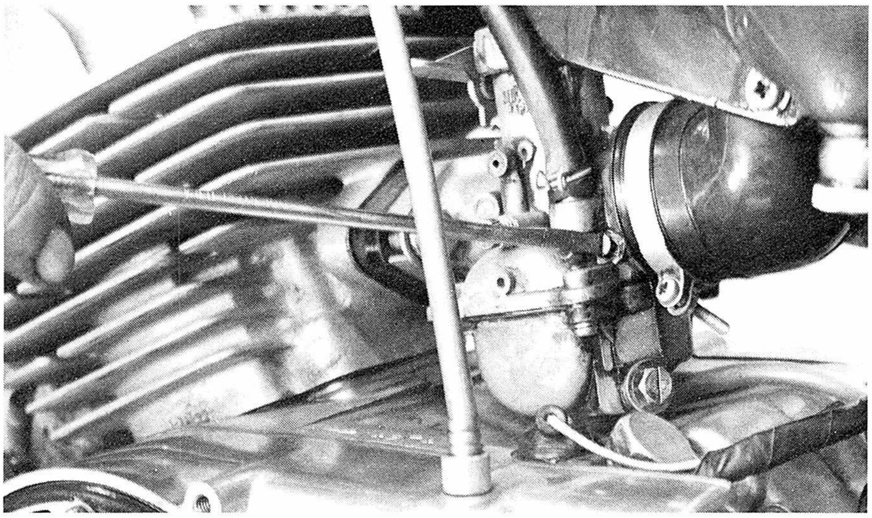

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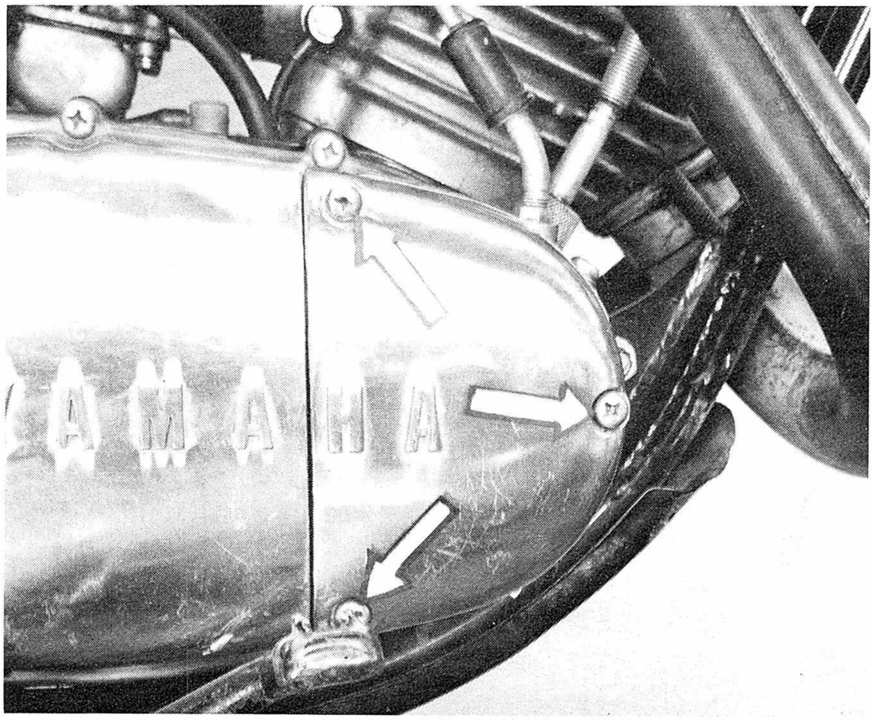

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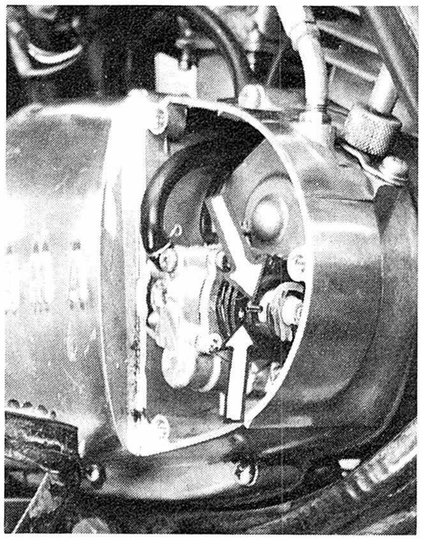
7. Next is the carburetor. Turn off the fuel tap petcock. Stuff a rag under the carburetor float bowl and remove the main jet holder. This will drain the fuel from the float bowl onto the rag. The rag will absorb the fuel, but any water will rest on top of the gasoline in sight.

8. Replace the main jet holder after inspecting the MJ orifice for obstructions. Turn on fuel tap. Turn the idle screw to bottom, then back out 1½ turns. Start and warm up engine then turn screw for smooth idle.

9. The oil pump should be checked regularly. If any oil is seaping from the cover this indicated a leak. To remove the cover take out three retaining screws with a phillips.

10. With the cover removed inspect the condition of the oil lines, clamp springs and cable for fraying. Also make sure the pump is securely tightened to the crankcase body. Otherwise serious damage can occur to the drive worm gears. Correct setting for the pin and eccentric cam should be done with the throttle closed. Therefore set carburetor idle position first. There is a small dimple on eccentric cam that must be lined up with guide pin. Don't lean oil mixture.

11. The guide pin is stationary, thus the eccentric cam must be moved by changing the cable tension with the adjuster shown by arrows.



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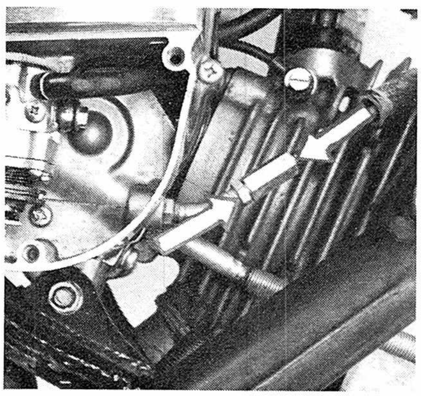

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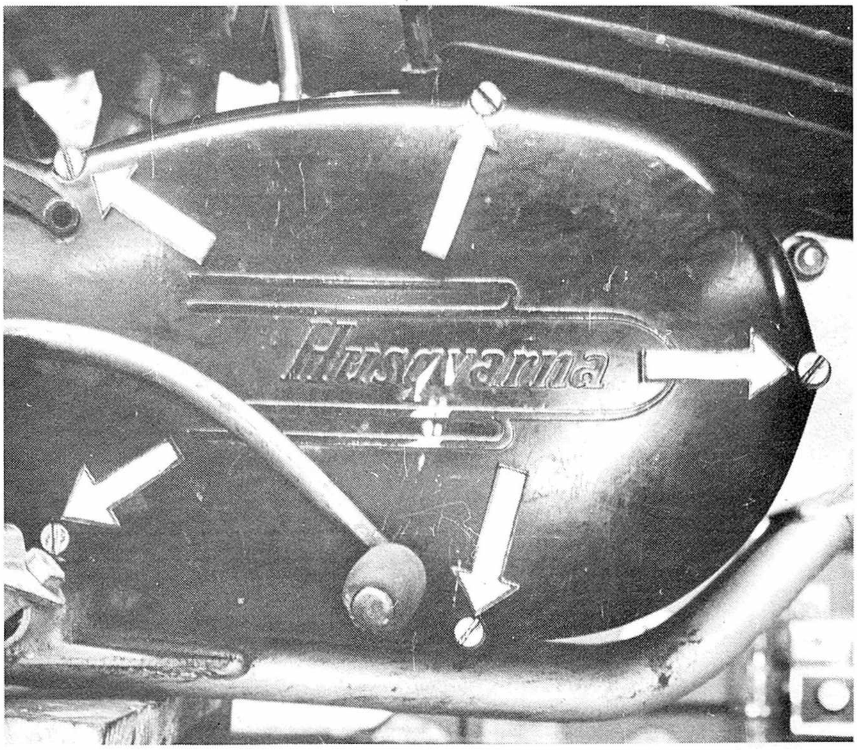
HUSQVARNA

While many changes have been made to update their products, Husky tuning techniques remain basically the same for all models

Ask the typical "Husky" owner what he likes most about his machine and he'll begin to sermonize on the mount with words like "handling" . . . "power" . . . "minimum of maintenance." It always seems to impress their owners that these Swedish competition machines will run and run and *run* with just a minimum of care. However, there is one item on this bike which should *not* go without periodical checking—the ignition timing. A machine does not "jump" time as some people believe, rather the engine gets out of time gradually. This usually can be attributed to wear on the point fiber where it rides on the point cam. Because this "detune" is gradual, often the rider doesn't notice that his machine is not running up to snuff. For reasons such as this, it behooves the rider to check the ignition timing frequently. We show it being done here with a "buzz box," but the same trick can be accomplished with a continuity light.



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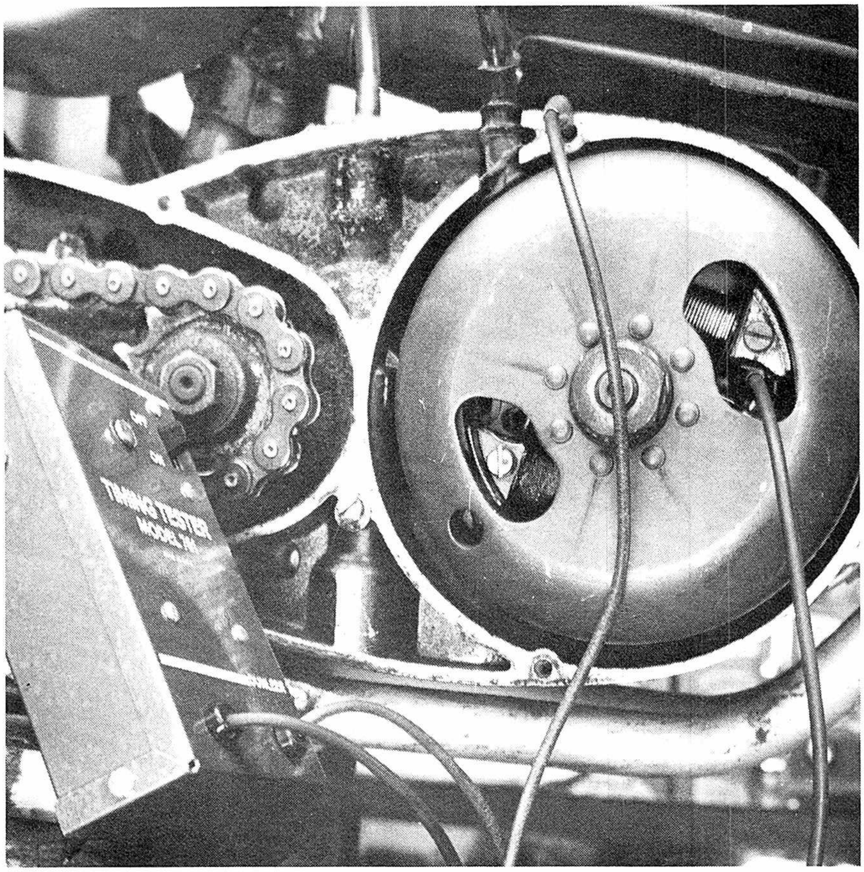
1. The right side case cover must be removed to work on the flywheel magneto. Remove the five slotted screws. You may have to use an impact driver to break them loose. The shift lever can stay in place. There is no need for a dial indicator.

2. With the cover off inspect the flywheel area for excessive oil build-up inside that would indicate a leaking crankshaft seal. Also look for any places on the sealing surface that might be leaking. Clean the points with Contact Clean and set the gap at .014 to .016 inch. Connect the buzz box leads to ground and to the points through the flywheel access hole. Twist clip to insure good contact.

3. At this point it will ease things to remove the spark plug to reduce compression restriction. As you turn the flywheel and run the piston to Top Dead Center you will notice a dimple on the flywheel is close to a mark on the forward part of the crankcase. These two marks should line up horizontally when the tone of the buzz changes and the points open. Watch that the buzz box clip doesn't snap loose while turning the flywheel.



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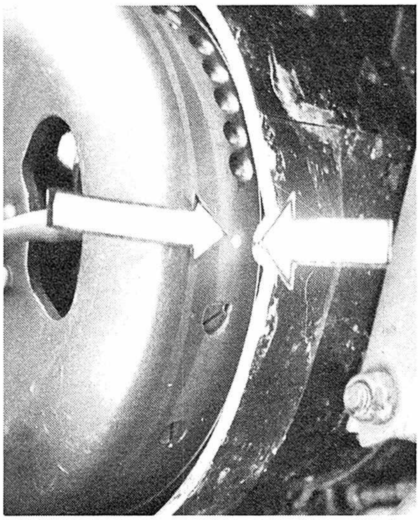

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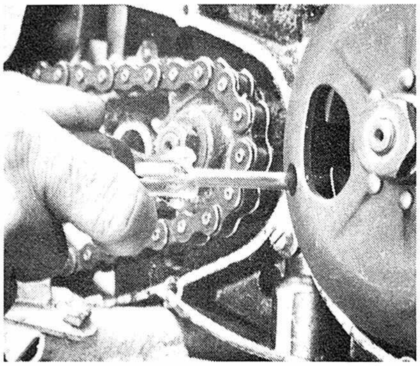
4. To enable the tuner to keep the point gap constant Husqvarna has included this extra hole to permit movement of the backing plate. To set the timing you reach through this access hole and loosen the backing plate screws. Now the point backing plate may be rotated to set the timing where needed. Once set, reverse procedure and tighten screws. Check the timing again after tightening screws as it can move slightly.



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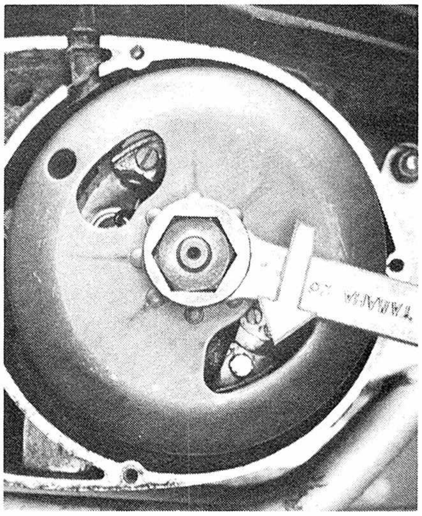
5. If the points and/or condensor need replacement the flywheel must be taken off. The retaining nut is 25mm across the flats, but this is an unusual size and wrenches or sockets are almost impossible to find. If you can find a 26mm six point hex wrench it will suffice. Don't use a larger 12 point socket as it will slip off. A tap on the end of the wrench should break the nut loose. Note that this nut is a left hand thread. The flywheel can be held from turning by placing the transmission in gear and pressing the rear brake.



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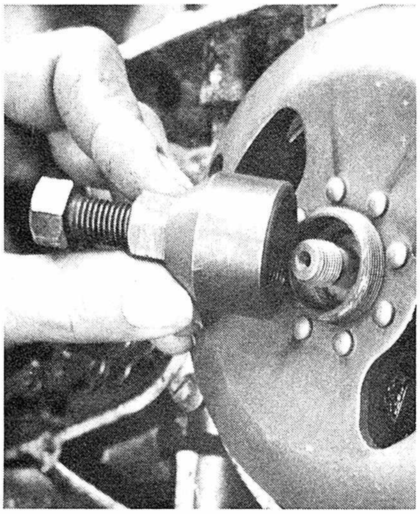

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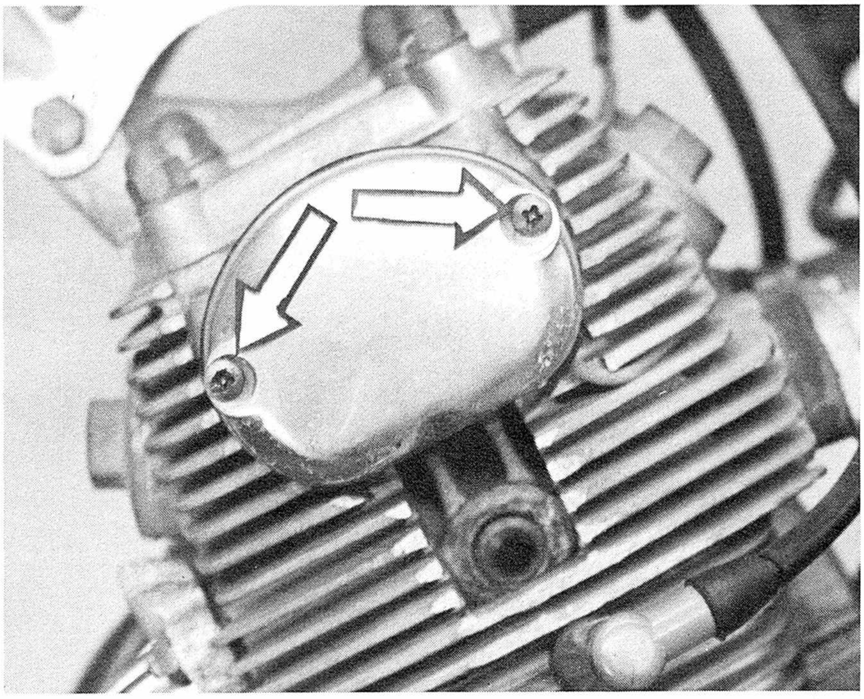
6. There is only one way the flywheel will come off the crank end, with a Husqvarna puller. Don't try to pop it off with any other tool. You can buy one from your local Husky dealer. While the flywheel is off check the condition of the wires and insulators. When replacing the flywheel be sure the woodruff key is lined up with the retaining slot. Once on the tapered crank end a solid tap on the puller will lock the flywheel in place. Torque nut to factory specs.

HONDA 160

The 160 represents Honda's breakthrough in dependable engine design. The 125 and 175 twins are subject to the same basic tuning drill

There is an ever-expanding group of motorcycle mechanics who believe that the 160cc model Honda is the best piece of equipment the Honda factory ever produced. It seems the 160s require a lesser amount of work performed on them per mile than do machines larger or smaller in displacement. Very rarely does one visit the shop except for a tune-up, and even these seem to be few and far between. It was with this success in mind that Honda decided to use the same basic engine design for their 125 and 175 twins. While there are a few differences, most of the tune-up procedure is about the same. If you are in doubt, however, check the specs in your handbook. As for special tools, the engine is designed to have the ignition checked with a strobe light and we recommend that you procure one for this purpose, although static timing is possible.



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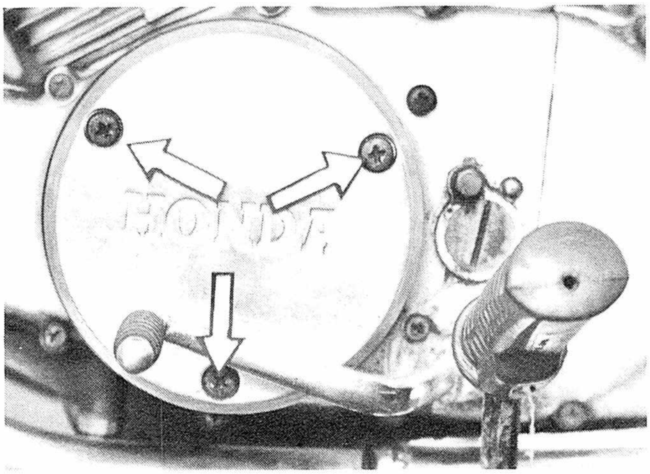

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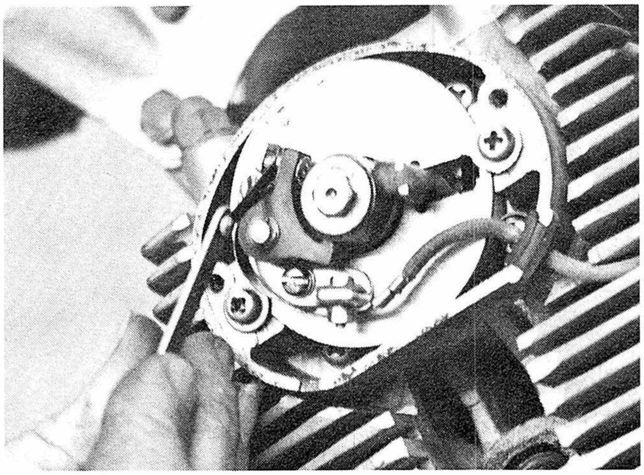

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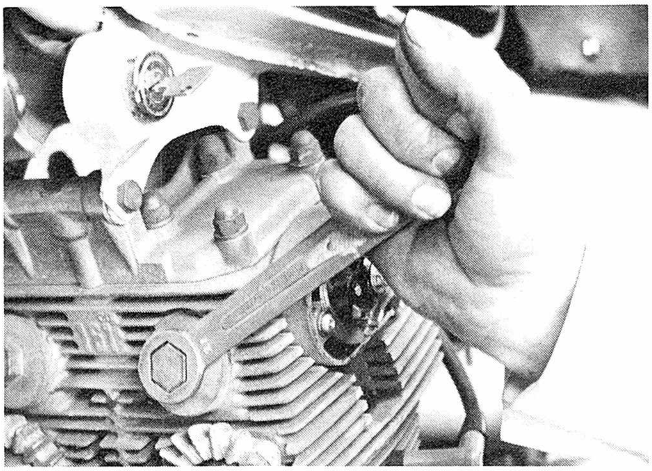

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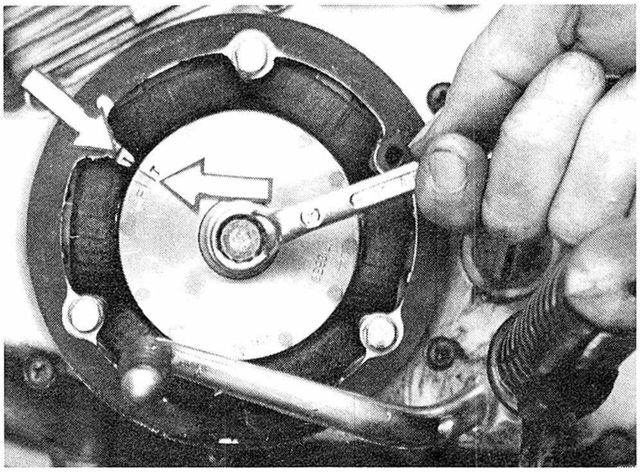

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1. Remove spark plugs, so engine can be rotated easily. Using a phillips screwdriver, remove the two screws holding the contact cover plate on cylinder head. Remove plate.

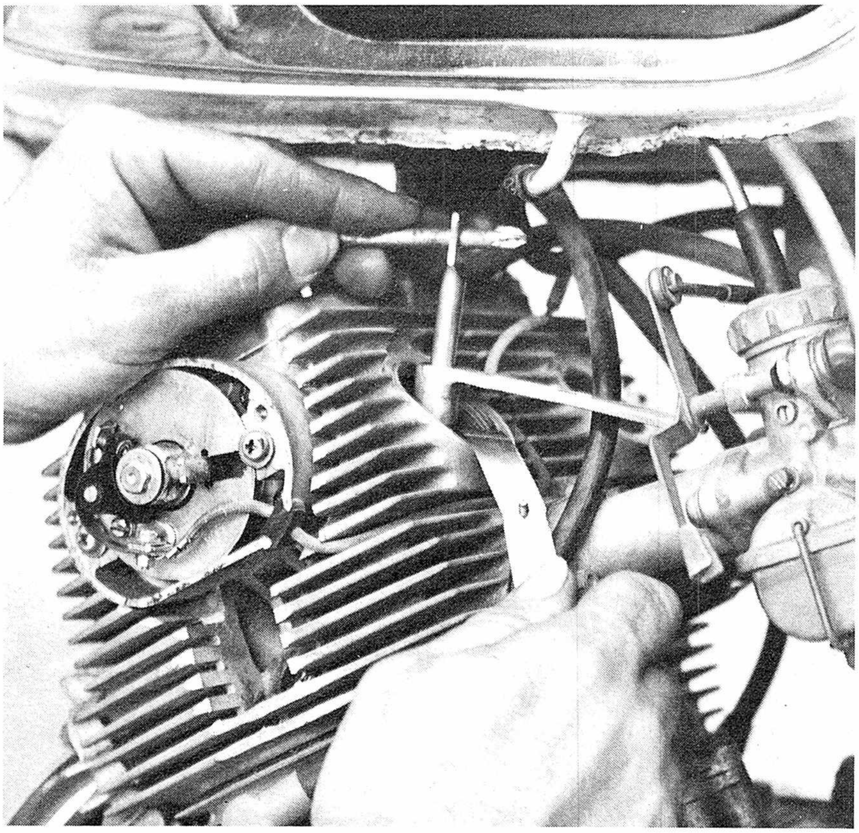
2. Remove the three screws securing the alternator cover, giving access to rotor. Also gives access to a 14mm nut which, with a proper wrench, can be used to rotate engine.

3. Clean points, then check to see if gap is .014–.016-inch at full open position, on either of the two lobes.

4. Remove all four rocker arm cover caps, using the 21mm tool kit wrench, if possible (six-point box prevents damage to nuts).

5. Watch left-hand intake valve rocker. Rotate engine until valve opens, keep rotating until "T" mark on rotor aligns with stationary mark as shown.

6. With engine positioned at TDC on compression for left cylinder, both intake and exhaust valve clearances may be adjusted on this side. Here again, tools provided in kit will do an excellent job. Factory recommends setting of 0.03mm–0.05mm (.0012–.002-inch) for both valves, but a good rule of thumb is a tight .002-inch on the intake, loose .002-inch on exhaust. After adjusting left-hand valves, proceed to adjust right-hand side.



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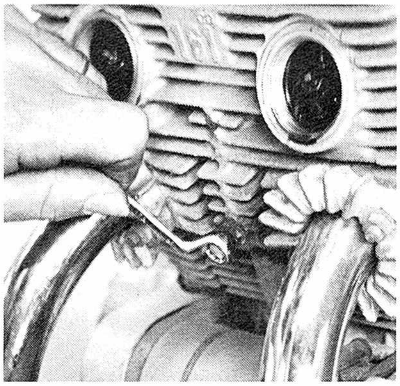
7. With engine remaining at "T" mark, adjust cam chain tension. Loosen lock nut on tensioner bolt. It is a 9mm nut. Then loosen the lock bolt one full turn and retighten, but do not over-tighten—just snug. The tensioner is spring-loaded, and requires no further adjustment.

8. Adjust the idle air screw on the carbs by running lightly to bottom, and backing out 1½ turns. If you have experienced high-speed misfiring, drop the float bowls off and check for water in them.

9. If you are timing with a "buzz box," connect one lead to ground, one to the contact point terminal. Rotate engine forward; the points should just break as the "F" mark on rotor aligns with stationary pointer as shown. This is the correct position, five degrees before top dead center.

10. If timing is off, loosen the two screws (arrows) and rotate point plate until correct. Recheck after tightening screws. This operation times both sides.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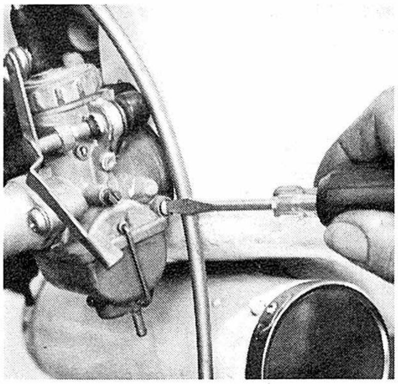
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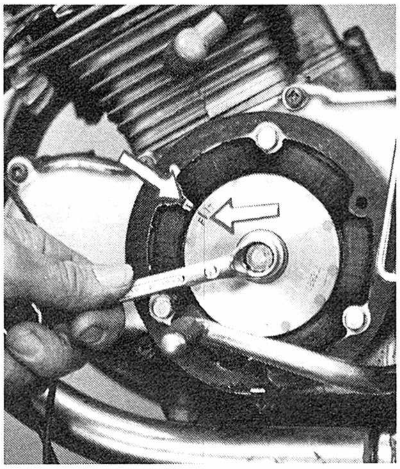
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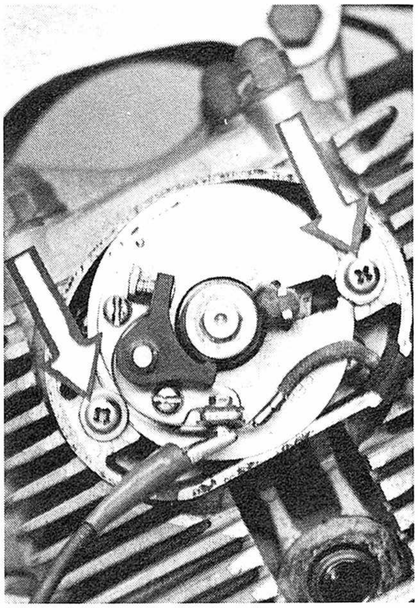
11. If a timing light is used, connect to an external power source, and start engine. To save getting an oil bath, a simple cover with port hole can be made, as shown from another cover plate. With engine at idle speed, the light should "freeze" the "F" mark at the stationary point as shown. If incorrect, adjust point plate.

12. To adjust clutch, first run the handlebar adjustment all the way in, then do the same where cable enters the case. Loosen adjuster locking bolt with a 10mm wrench. Using a large screwdriver, turn adjuster to right until you feel interference with clutch push rod. Back off about ½ turn and retighten locking bolt. Any play in cable should be taken out where it enters case. Be sure to leave correct amount of play at lever.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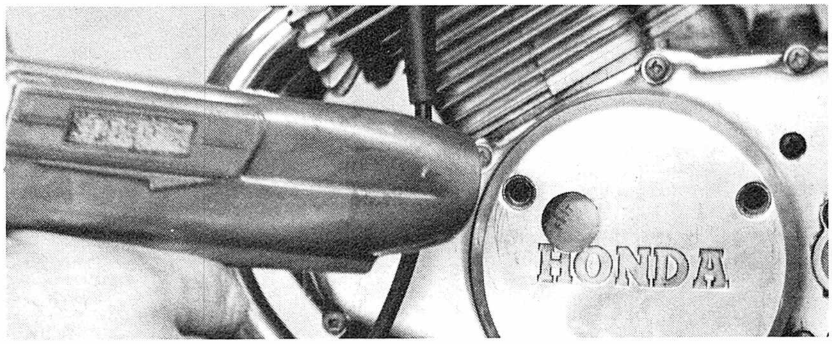

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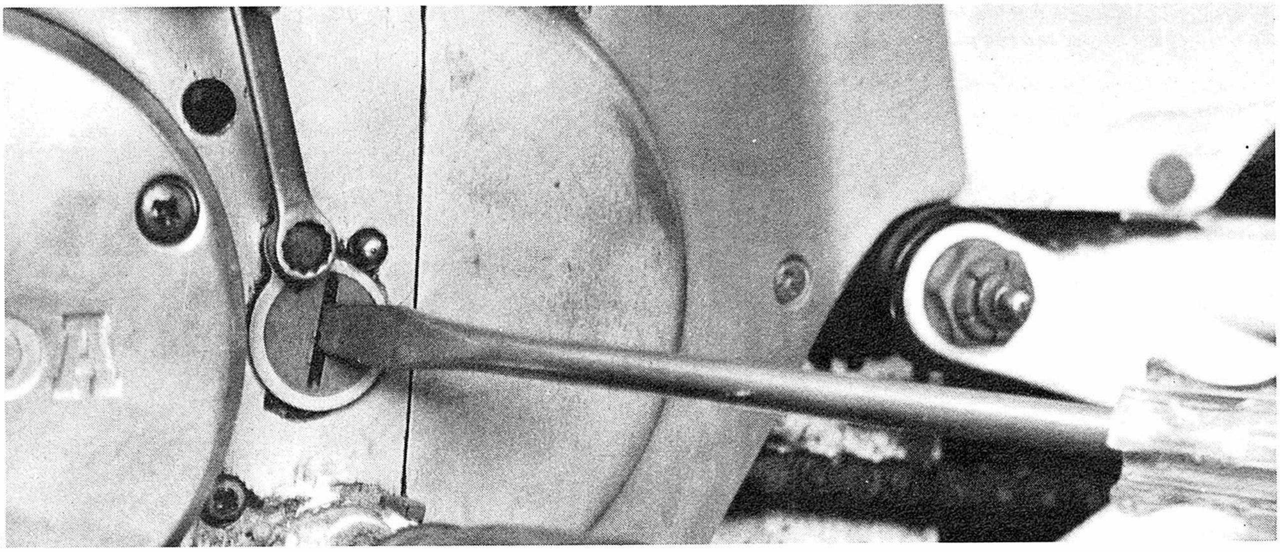
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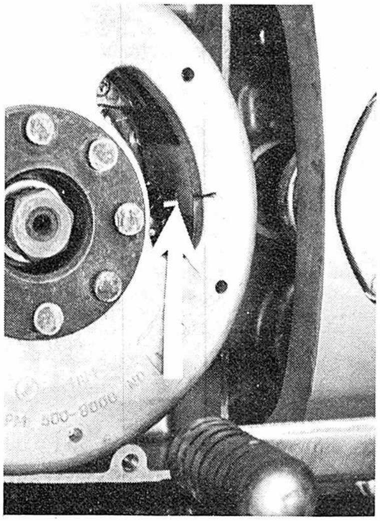
YAMAHA DT-1 ENDURO

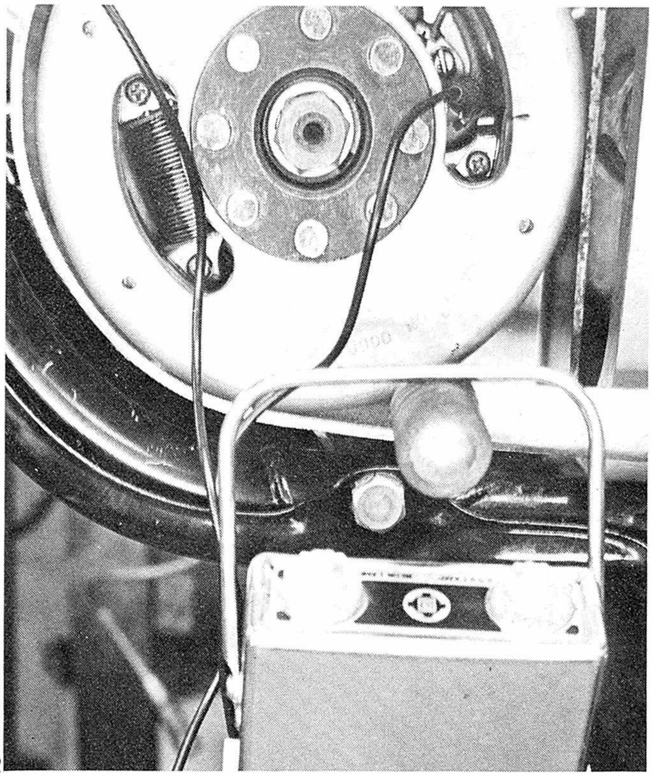
Except for timing specs, the 250cc DT-1 has the same battle plan as the 175 and 360. On the 360, advance mechanism must be operated manually to check timing

The DT-1 Yamaha could be called "the Father of all Enduro models." While there were many companies in the early days who made machines for use as off-road vehicles, they were too specialized in their preparation. None of the so-called street/dirt machines really hit it big until Yamaha exploded on the American scene with the DT-1. The instant success of this model prompted Yamaha to branch out into myriad other size machines; these too have enjoyed popularity. One of the things which endears them to the average rider is their ease of maintenance. With a bare minimum of tools, the owner can keep his machine at peak running condition and enjoy many miles of trouble-free riding. While there are some big differences in many of the Enduro models, the tuning procedure remains about the same for all. A glance at your handbook will tell you the important differences to look for when tuning your particular Enduro.



1. The high-stepping DT-2MX retains many features of the forerunner DT-1. Magneto is under left-hand engine cover held by two screws on early models and four on later ones. Ignition timing is accomplished by coinciding alignment of flywheel mark and fixed pointer (arrow) with opening of the contact points.

1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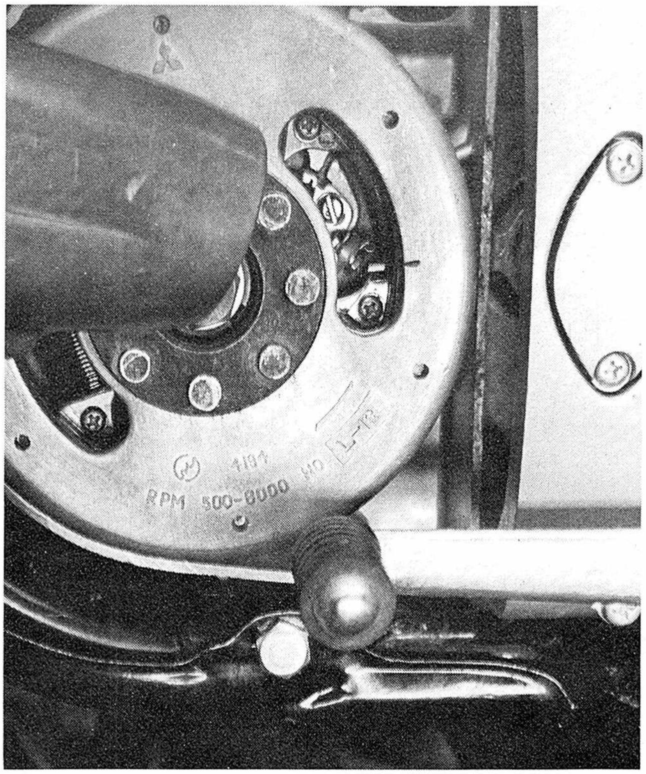
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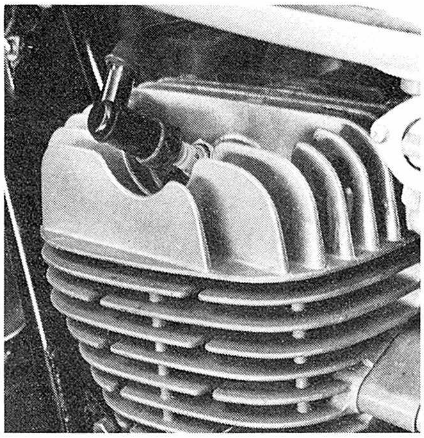
2. Most popular method of setting timing is with 'buzz box' or ohmmeter. Ground one lead, attach other to point terminal and rotate engine slowly forward. Buzz box should indicate contact opening just as lines are adjacent to each other.

3. Same result can be obtained using timing light. Only disadvantage is that timing is adjusted by opening or closing point gap. This means engine has to be stopped each time adjustment is made, then restarted (unless you have the 'Fastest Screwdriver in the West').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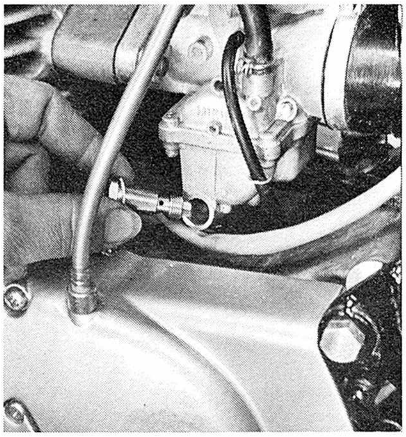
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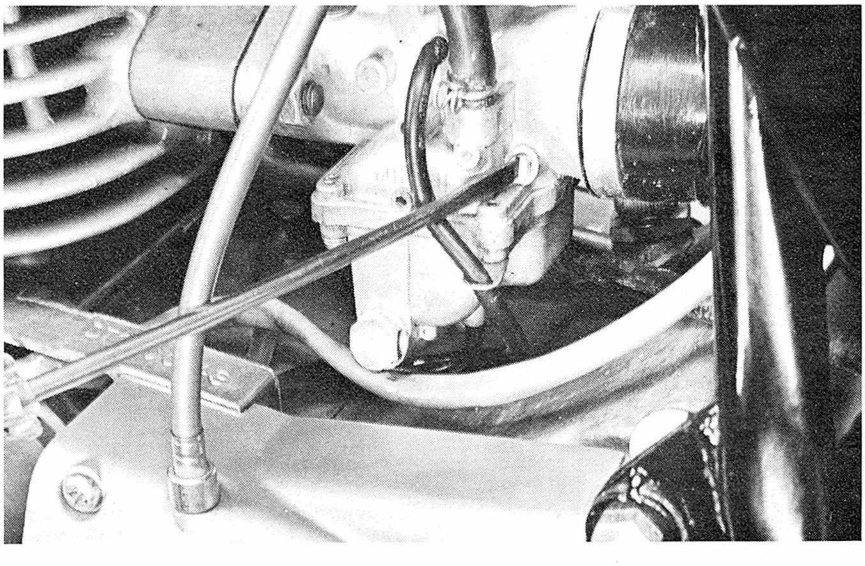
4. Angled position of sparkplug in head prohibits use of dial indicator for setting timing. If head is completely removed, indicator can be used. In this case, setting is 3.2mm (0.126 in.) Before Top Dead Center. Always install a new sparkplug when tuning up.

5. One of the biggest advantages of the Mikuni carburetor is the easily changed main jet. Early models came with a 150 stock main jet. Removal of this jet holder also allows draining of the carburetor to rid it of any foreign matter that may lead to fuel problems at a later date.

6. As with most of the Mikuni carburetors, the plan for setting the idle air screw is to run it all the way to the bottom (gently), then back it out 1½ turns. After the engine is thoroughly warmed up, one quarter turn either way will usually insure you of a good even tick-over.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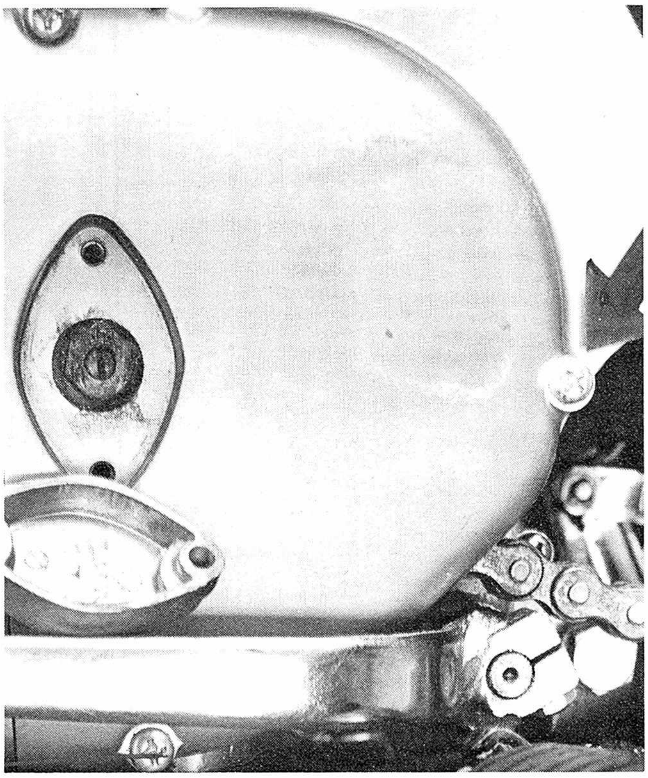

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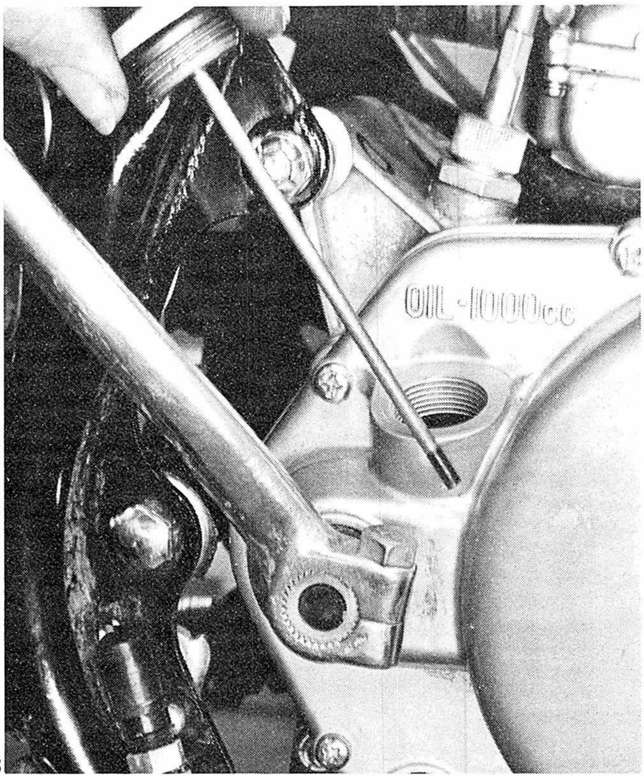

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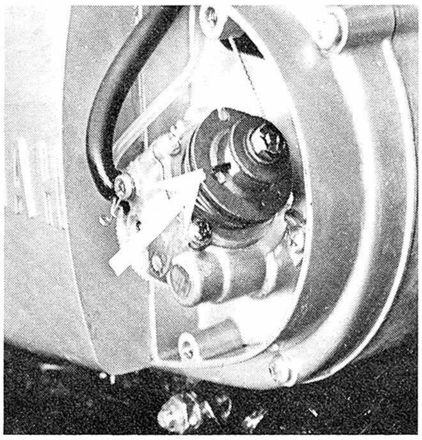

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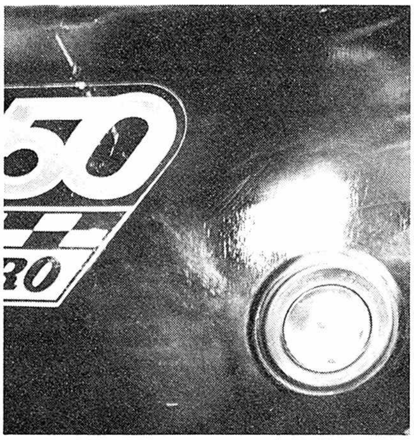

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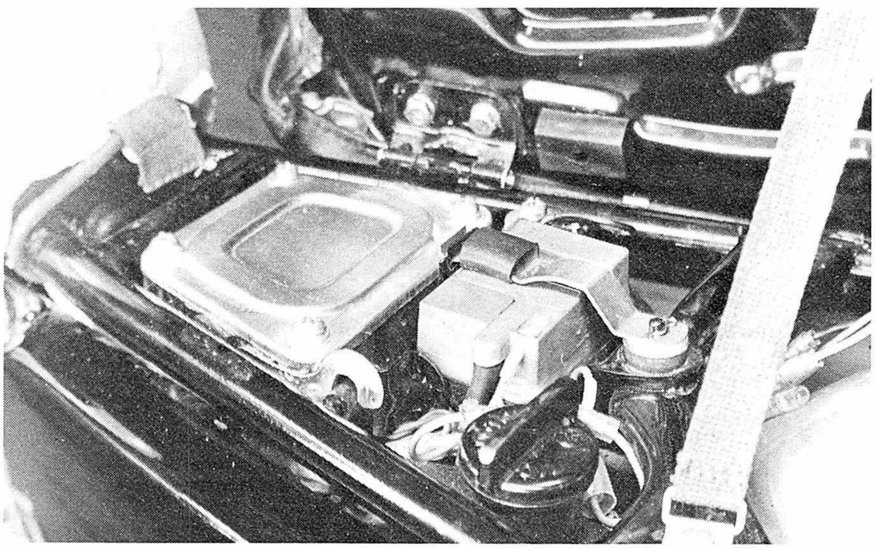

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7. This small cover just aft of the magneto cover gives access to the clutch adjustment. Loosen the jam nut, turn the screw in till it just bottoms, back off ¼ turn and tighten the jam nut. Three screws hold the larger drive sprocket cover in place. Don't use a sprocket smaller than 14 teeth or chain movement could break the screw boss (arrow).

8. Oil filler plug has a built-in dip stick. With the plug just setting in the hole, oil should just cover the flat spot. The 'OIL-1000cc' cast into the engine refers to the amount required for the gearbox/clutch when changing the oil. This is only 54cc more than a quart.

9. Two screws hold the oil pump access cover in place on the right-hand engine side case. Make adjustment so that the small pip (arrow) on the cam plate lines up with the roll-pin at idle. This is done through the oil pump cable adjuster located just above on the case.

10. Small window on the oil tank is to tell you if the supply for the engine injector pump is low. If possible, the tank should be topped up with a good grade of 2-cycle motorcycle oil at each outing.

11. To save the expense of light bulbs, always check the water level of the battery. Remove the battery from the bike and set it on the bench for accurate check. While not actually in the headlight circuit, the battery does act as a buffer in the alternator system, and a dry battery could cause the blowing of the headlamp bulb.

HONDA 750 FOUR

Aside from a difference in carb synchronizing and adjusting the cam chain, the 750 and 500 have a lot in common from a tuning standpoint

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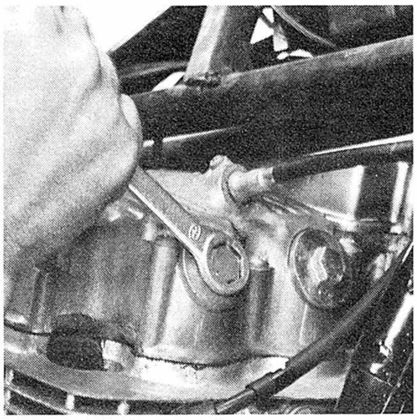

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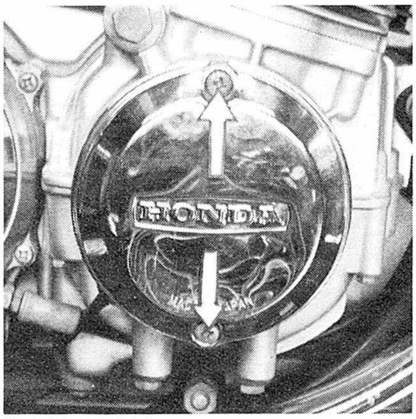

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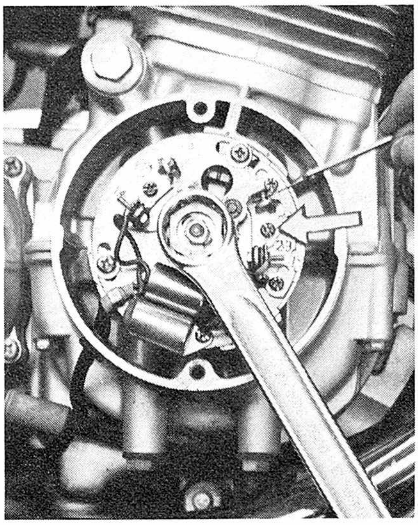
There is precious little doubt in anyone's mind (especially Honda dealers) that the Honda four is the consummate success story. The instant acceptance of this model by the buying public has been no less than fantastic. It seems to combine all the ingredients the street rider desires in his road steed: Brute horsepower, a decent purchase price, reliability, available accessories, electric starter . . . and that beautiful exhaust note doesn't hurt, either. The only drawback (if you can call it that) is that the rider who is accustomed to tinkering with his machine gets apprehensive about touching his new Honda Four. For some reason, the very fact that the machine has four cylinders makes one tend to view it with awe and reverence. This model Honda bears a certain kinship to a Rolls-Royce in that it makes the owner think only of taking it into a dealer for service. The idea is that only this *anointed* person should be allowed to touch such a machine. For complicated service work, this is indeed a good attitude to have. It can save you dollars in the long run. But for simple maintenance and engine tune-up, there is no need for the rider to back away. With a minimal outlay for tools and a little care in using them, he can save many times over the cost of one tune-up alone.



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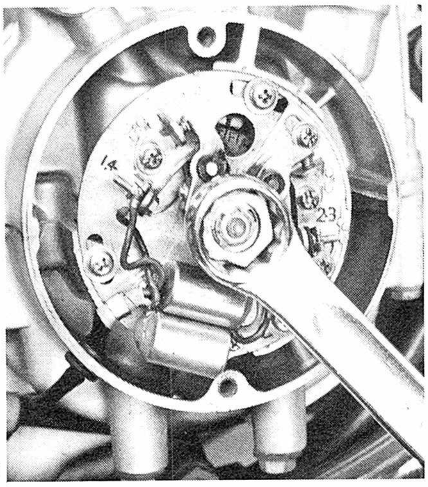
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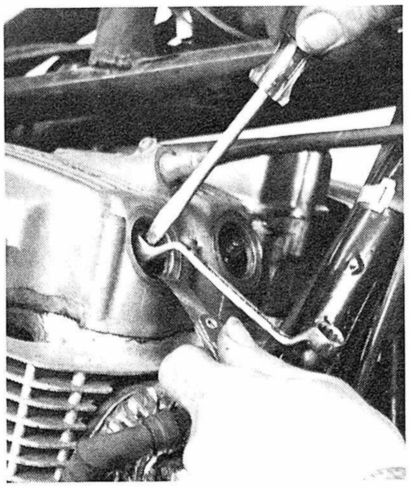
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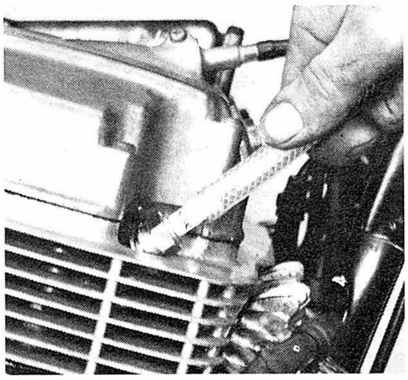
1. Remove the gas tank. It is impossible to do a tune-up with the tank in place. Use an 18mm socket to remove the four spark plugs. Note the universal attachment on the plug wrench, making it a lot simpler to remove the middle plugs. This is an inexpensive item available from your local Sears-Roebuck store.

2. Use a 17mm wrench to remove all eight rocker box inspection caps. To avoid damage to the hex-head on the caps, do not use an open end wrench. The box wrench shown here is a tool kit item which, if lost, can be replaced with a small investment at your Honda dealer.

3. Take out the two Phillips screws and remove the chrome cover on the right side of the engine. This will expose the contact points as well as the factory marks for ignition timing. Clean and burnish both sets of points.

4. Rotate the engine by using a 23mm wrench on the center nut as shown. Watch for the points to be opened to their widest. The point gap should be set at .012–.016 in., a good standard is .014 in. Adjustment is made by loosening the point mounting screw (arrow) and levering with a screwdriver. Note that each set of points is marked for the cylinders that they control.

5. The cylinders are numbered 1 thru 4 from the left. Rotate the engine forward until the inlet valve for No. 1 opens, then begins to close. Now continue forward slowly, watching through the aperture in the top of the point plate. When the 'T' & 'F' marks (designated 1-4) come into view, align the 'T' mark with the pointer as shown. Now adjust the intake valves on cylinders one and three and the exhaust valves on one and two. Set the intake clearance at .002 in. and the exhaust at .003 in. Now rotate the engine one full turn forward and line up the same marks, putting the No. 4 cylinder on TDC compression stroke. Adjust the intake valves on two and four and the exhaust valves on three and four. This is the 'flat-rate' alternative to the system of positioning each cylinder at TDC and setting them individually.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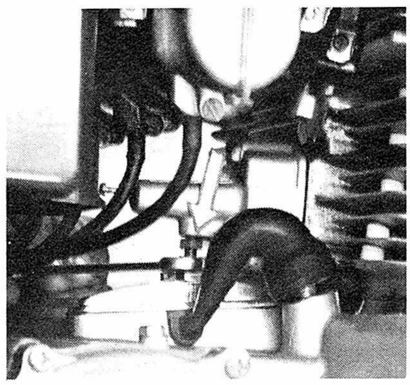
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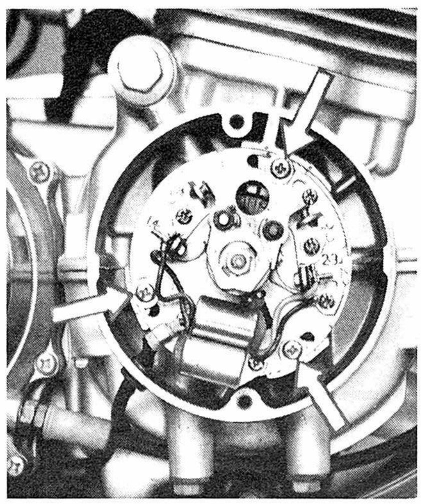
6. When adjusting the valves, try to use a 10mm box-end wrench instead of an open-end. This will avoid rounding off the lock nuts. Set the valve clearance so that there is just an ever-so-slight drag on the feeler gage. Hold the adjuster firmly with the screwdriver while tightening the lock nut. Check clearance after tightening. Re-install all inspection caps except those on No. 1 cylinder.

7. Lightly lubricate the threads of the new spark plugs. Gap them at .020 in. and install. The center plugs are rather difficult to reach and can be very easily cross-threaded. Slip a section of fuel hose over the plug as shown so that too much force can't be put on the threads when starting them. Run them in as far as possible with the hose, then tighten with the wrench. Now install the gas tank, and hook up the fuel lines.

8. With the valve inspection caps off of No. 1 cylinder you can see the rockers for positioning No. 1 at TDC. Rotate the engine about 15 degrees further forward of this to position the cam chain for adjustment. Loosen the cam chain adjuster lock nut (arrow), and back off the adjuster bolt. Now run the bolt back down to JUST SNUG, and re-lock the nut. This automatically adjusts chain tension with an internal spring. Replace the inspection caps on the No. 1 cylinder.

9. Install timing light adapter on No. 4 spark plug. The light must be connected to an external power source, do not use the battery on the machine. Start the engine and direct the timing light into the aperture in the point plate to observe the timing marks. The correct ignition timing for the No. 1 and No. 4 cylinders is when the 'F' mark designated '1-4' aligns with the stationary pointer at slow idle. The timing light will 'freeze' the marks where the engine fires.

10. If timing is off on cylinders 1 and 4, loosen three screws (arrows) and rotate plate to align marks. This changes timing without changing point gap. Re-check timing after tightening the three screws.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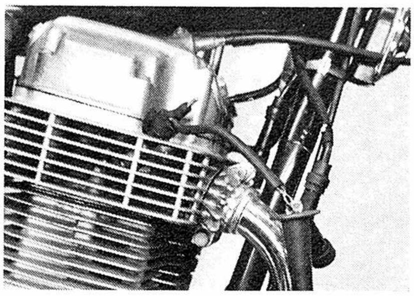

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11. A timing light adapter like this is almost a necessity for checking timing on cylinders 3 and 4. One can easily be made from a spark plug connector cap, a piece of high tension wire and a small screw. The regular plug wire snaps on the screw extension on top.

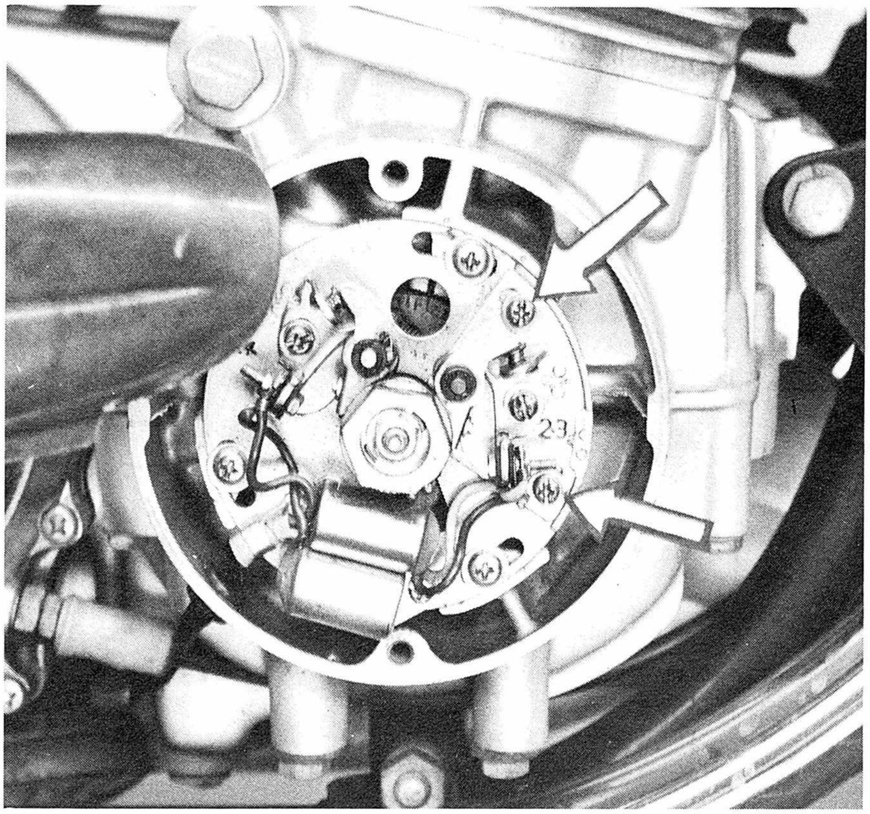
12. Using the adapter, connect the timing light to the No. 3 plug. Start the engine again, and at a slow idle, align the 'F' mark designated '2-3' with the stationary pointer. To adjust the timing on this set of points, loosen the two screws shown which secure the points identified '2-3.' They can now be adjusted individually. Again, re-check the timing after tightening the screws.

13. To adjust the carburetors, you will have to remove the air cleaner box. For air cleaner access, remove the two thumb screws at the bottom of the box (arrow). Remove the filter element and gently blow it clean with compressed air. Loosen all four clamps that hold the box to the carbs with a Phillips screwdriver. Now the two bolts on top (arrow) that actually hold the box can be removed. There is one on each side and take a 10mm wrench.

14. With the air cleaner removed, you are ready to set the carburetors for proper engine idle. Turn the idle air screws gently to the bottom and back out one full turn as shown here. This will give you a good starting position for final adjustment after the air cleaner is installed. If you have one of the expensive factory gages, just remount the air filter after cleaning it.

15. If you do not own a set of these gages (they come with complete instructions), here is an economical tool for you. It is called Uni-Syn and was designed primarily for use on sports car carburetors. It can be purchased at most auto parts stores for about $10. Quite a savings over the factory model!

16. Start the engine and warm it up. Set it to idle as evenly as possible. Place the Uni-Syn against the carburetor so that the soft rubber seal covers the mouth of the carburetor with the orifice centered. Always keep the gage tube in a vertical position. Slowly turn the tapered plug for the induction hole of the Uni-Syn in a clockwise direction. This will cause the red indicator button to rise in the tube. Adjust it until it stops at one of the indicator marks (arrows).



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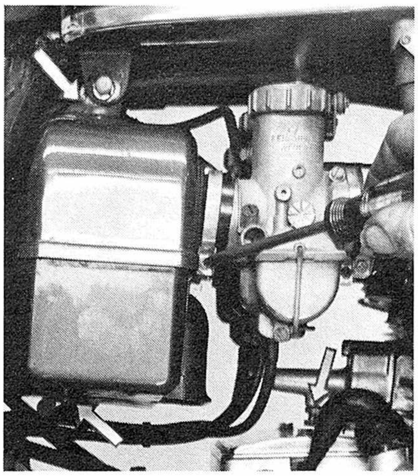

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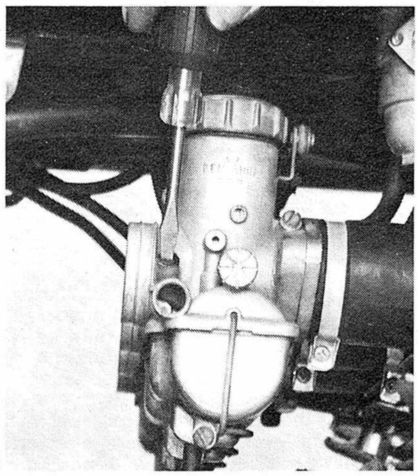

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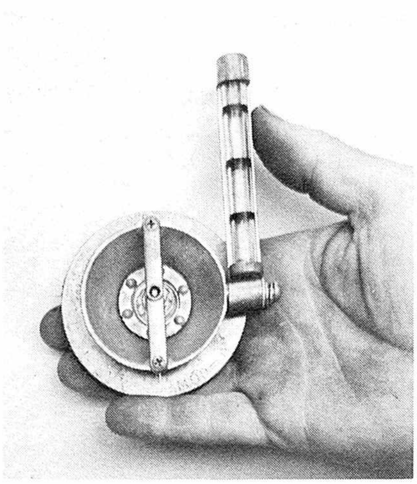

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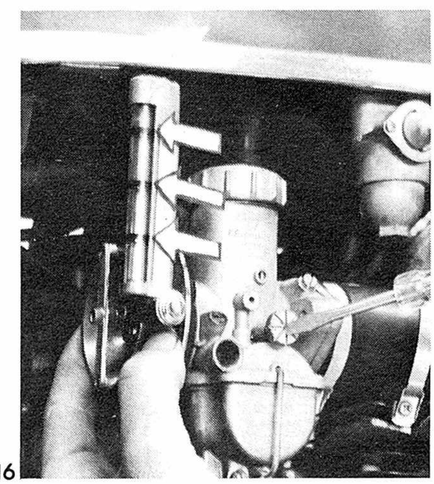

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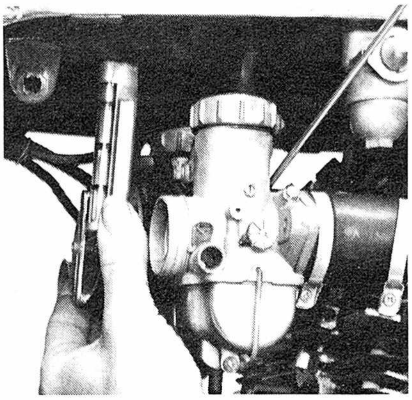
17. Be sure to keep the tube in a vertical position and do not change the adjustment of the Uni-Syn. Move to the next carburetor and adjust the idle to set the indicator button at the same mark. Continue doing this on each carburetor until the button is at the same spot on all of them. If the idle increases or decreases from the desired setting, reset and start over. Re-check a couple of times. This may take more time but costs less.



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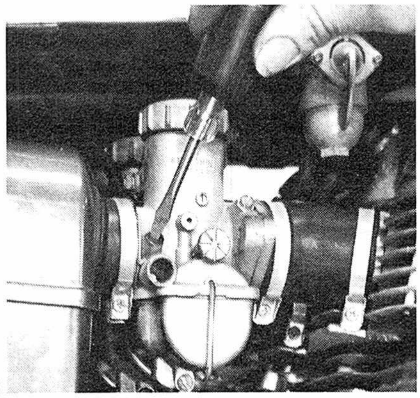

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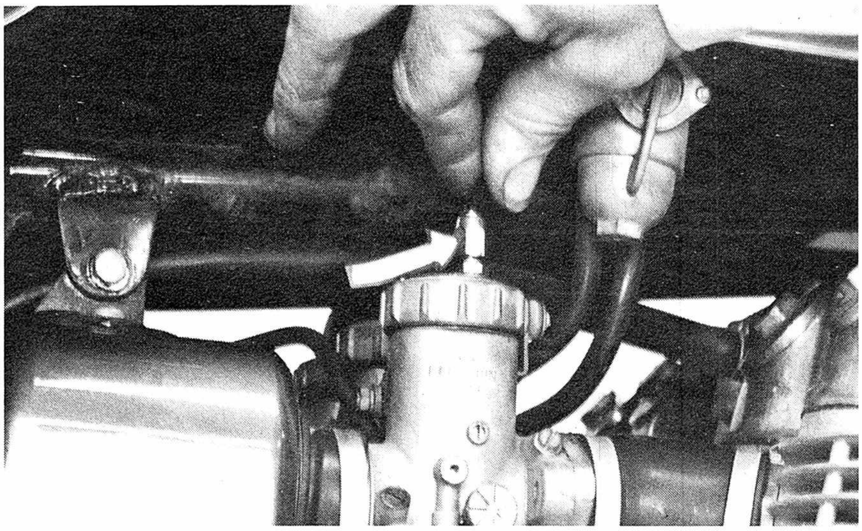
18. Re-install the air cleaner. Start the engine and make final adjustment on the air screws to get a smooth tickover. The setting should not have to change more than ⅛ turn. A dirty air cleaner will cause lumpy idle and high speed mis-fire; if yours is filthy, replace it.

19. Last step is synchronizing the slides. With the engine off, turn the twist grip to full open throttle and hold it there. With the tank propped up, pull up on each of the cable housings at the top of the carburetors. If there is any play, it means that the slide is lifting late. Using the adjuster at the top of the carburetor (arrow), remove the slack while holding the throttle full open.



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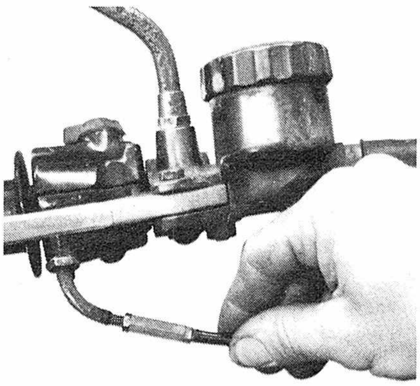
20. Now remove the slack from the top cable section. Using the cable adjuster just below the twist grip, take out any excessive play in the throttle. Remember there must be a slight bit of play in the throttle to compensate for the forks turning from side to side, or the engine will rev up.



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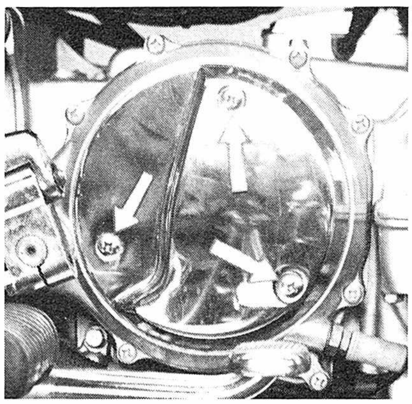

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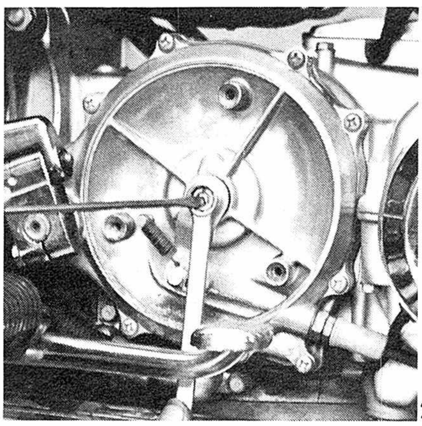
21. For clutch adjustment, remove this chrome cover. You will have to block the starter lever down for access to all three screws securing the cover (arrows). There is no need to place an oil pan under this cover when it is removed, as it only covers the clutch throw-out unit and has no oil in it.

22. When adjusting the clutch, first run the cable adjustments all the way in, at both the handlebar end and at the point where the cable enters the housing, to get as much slack as possible. Using a 12mm wrench as shown, loosen the lock nut on the adjuster. With a screwdriver, run the adjuster in until a resistance is felt, then back off one-quarter turn. Hold it in position with the screwdriver, and lock the nut. Take all but about one-quarter inch of cable play out with the adjuster at the case. Using the hand lever adjustment, make the final setting.



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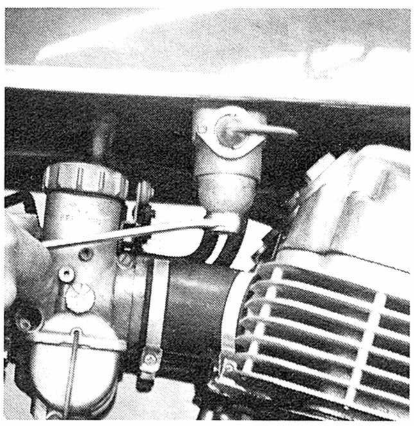

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23. A good habit each time you tune the engine is to clean out the sediment trap located on the bottom of the fuel tap. It is easily removed, using a 14mm wrench on the cast-in hex, as shown. Clean out any foreign matter or water that has been trapped within. Before replacing it, put a light film of grease on the lip of the bowl that contacts the seal. This will prevent cutting the seal and causing a leak.

HONDA 100

Here is a case where Honda's excellent 100cc engine design is carried over into the 125cc single, with the same basic tuning procedures applying

The 100cc Honda is a brilliant example of the idea, "if a little is good, a lot must be better." While the machine differs quite a bit from the S-90, there is enough similarity to see that it grew from the same philosophy. In fact, the "100" worked so well that Honda went on to develop a 125 single and, eventually, the 250 single. The 100 and the 125 use practically the same techniques in their tuning procedure; the 250 does not. One thing you will notice in the accompanying photos is the absence of a gasoline tank. The reason for this discrepancy is that the tank is so easy to remove it is absurd to fool around trying to work around and under it. Again, the only necessary tools other than those found in the tool kit are the timing light and an impact driver. For those of you not familiar with the impact driver, it is the greatest boon ever invented for the mechanic working on Japanese machines. It will remove the most stubborn phillips screws without tearing the heads up, and should be a "must" part of your tool ensemble. One can be picked up at your local dealer.

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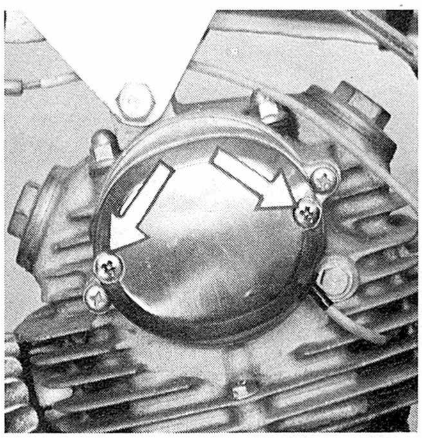

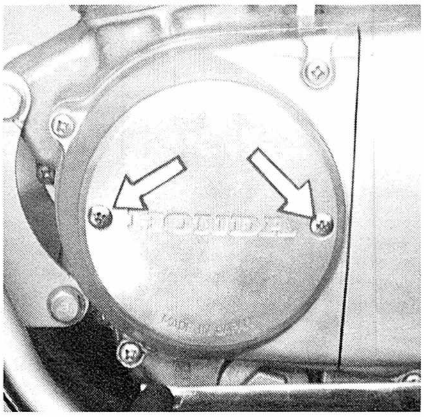

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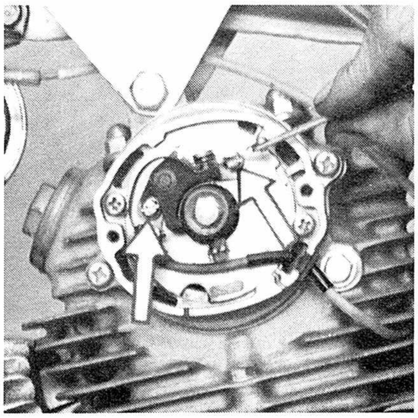

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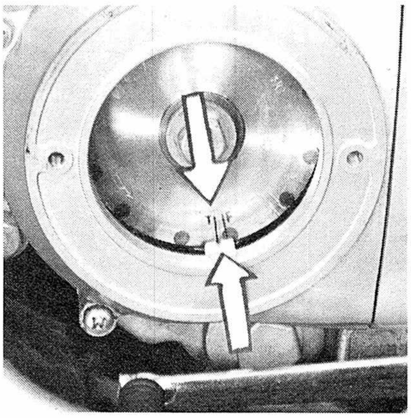

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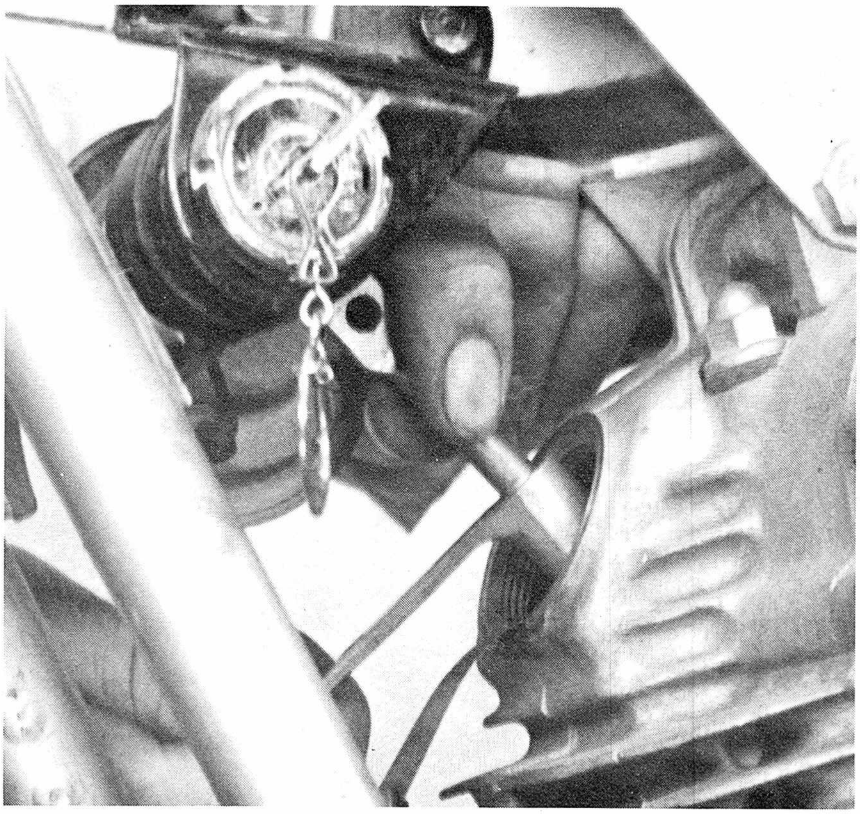
1. To ease accessibility remove the gas tank. You will have to take off the seat, disconnect the fuel line then lift the gas tank back and up. This will enable you to get to the rocker caps. The points are located on the end of the overhead camshaft. Access to the points is acquired by taking off the tin cover after removing the two phillips head screws.

2. Still on the left side of the engine go down and remove the two holding screws on the alternator cover. A light tap with a mallet should knock the cover loose.

3. Clean the point area with compressed air or Contact Clean. Inspect the wires and insulators for corrosion or damage. Inspect the contacts of the points and if excessively pitted replace along with condensor. Clean with Flex-Stone strip and business card. Set point gap at .015 inch. Loosen two plate fastening screws to open or close points for setting

4. Go back down to the alternator rotor and rotate the engine with a 14mm wrench until 'T' line lines up with stationary mark. This must be done on the compression stroke. To determine the compression stroke remove the exhaust valve rocker cap (front). Rotate the engine and just after the exhaust valve closes, compression starts.



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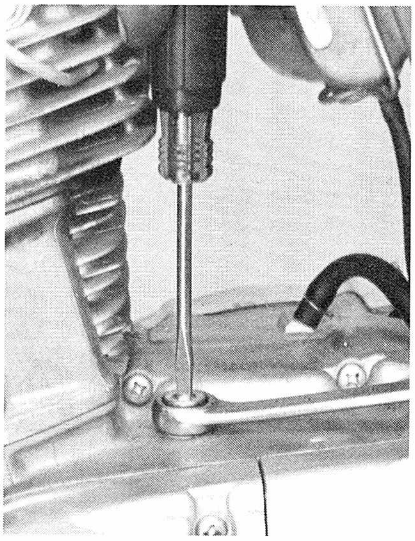
5. Remove the intake valve rocker cap also. Rotate the engine until the piston reaches Top Dead Center. Go to the exhaust valve, loosen the lock nut and set the clearance at .002 inch. Tighten the lock nut and check the clearance again. The feeler gauge should drag through the gap.

6. Adjustment of the cam chain tension is simple. Remove the rubber cover from the adjuster nut on the left side of the engine. Loosen the lock nut with a 14mm wrench. Back out the adjuster with a slotted screwdriver beyond the tension point. Then run the screw back in until tension is felt.

7. Install a new spark plug and set gap at .020 inch. Connect a timing light to the spark plug lead. Adjust the carburetor so the idle is slow. The strobe light should freeze the 'F' timing mark and indicator.



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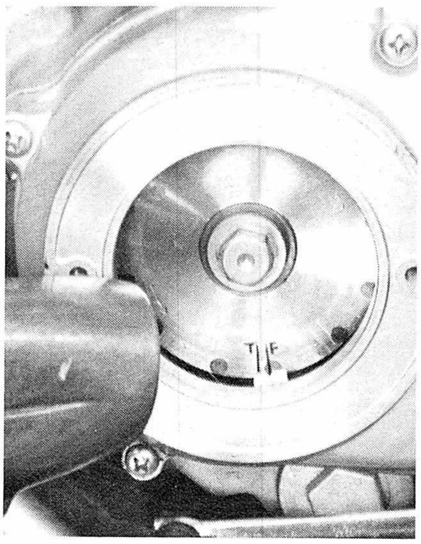

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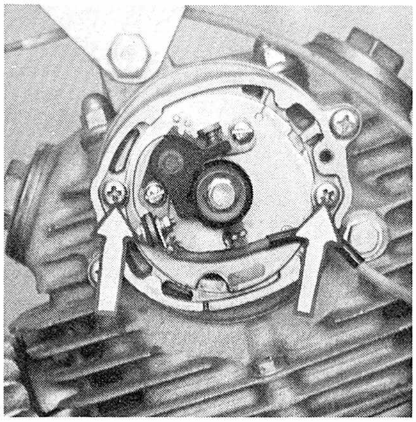
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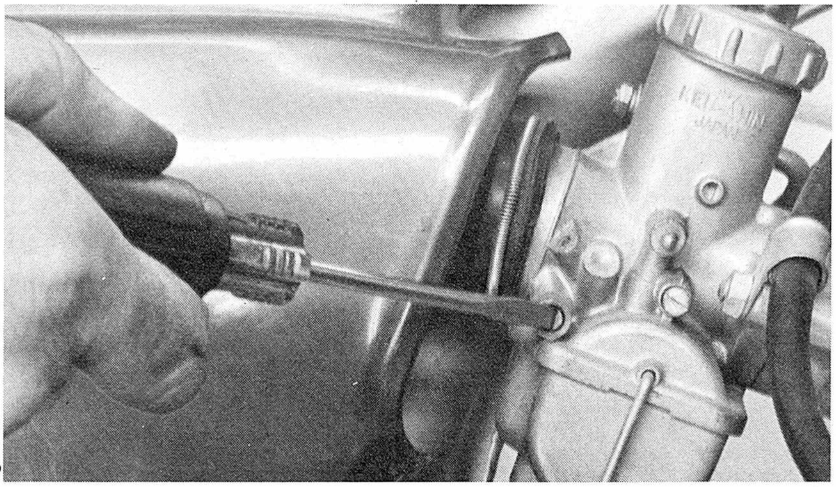
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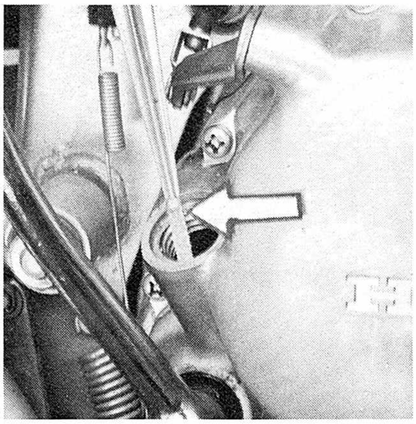
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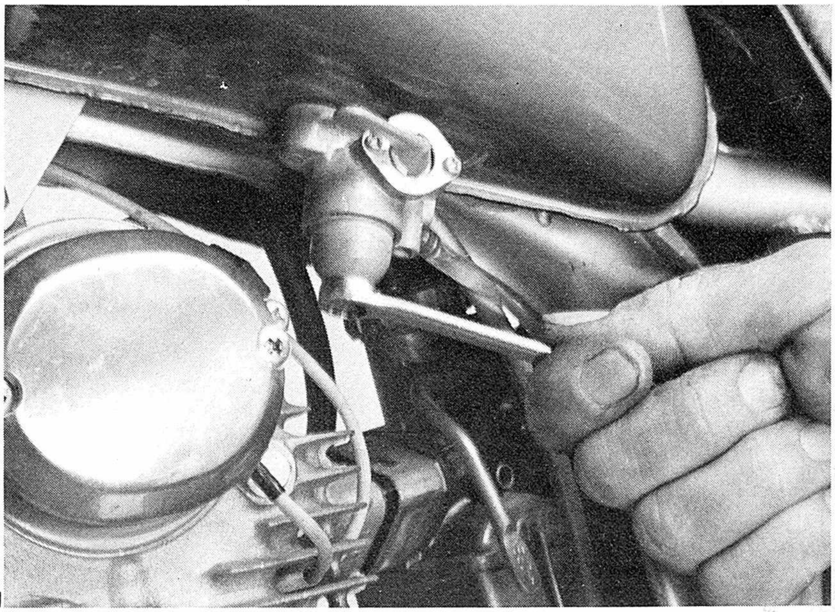
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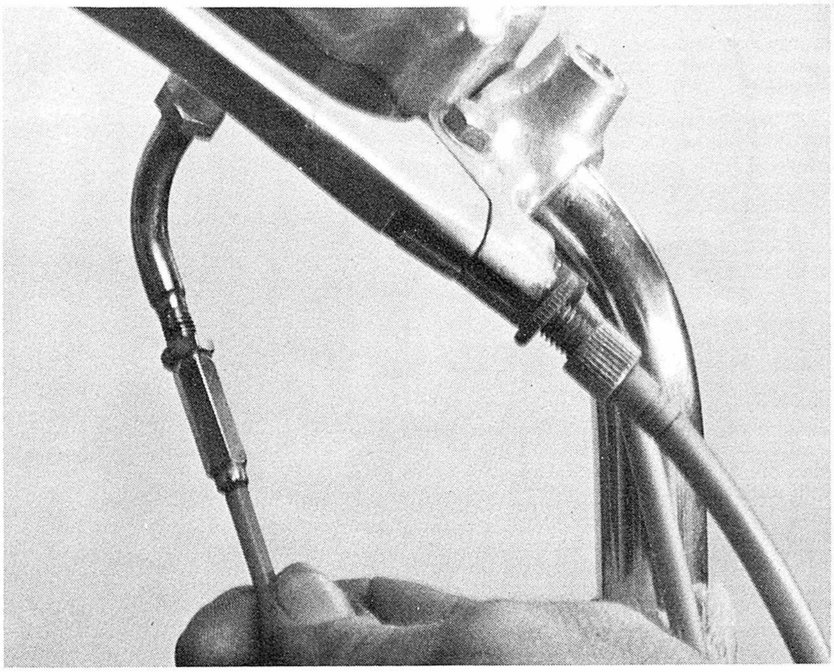
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8. To set the timing loosen the holding screws on the backing plate. A notch is cut into the plate at 2:00 o'clock that permits levering with a screwdriver. Move the plate until the correct timing position is located then tighten screws. Check timing again as tightening screw can move it.

9. The carburetor will require some attention. Remove the float bowl by prying wire retainer off. Look for water accumulation on top of the gasoline which would suggest cleaning out gas tank also. Clean out sediment in the bowl. To set the idle run the screw to bottom, then back it out 1½ turns. A quarter turn either right or left should set the idle.

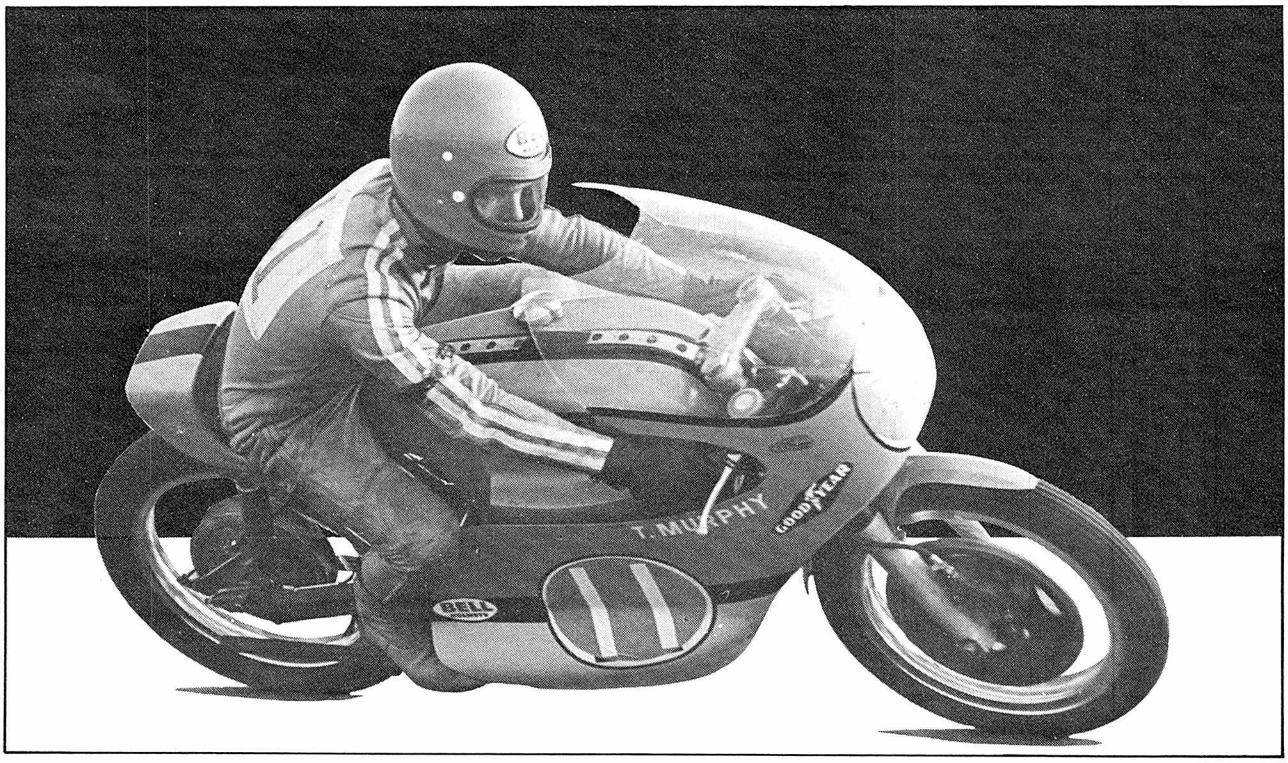
10. Check the oil level. Remove the dip stick, then set it back in the opening (don't screw it in). Oil should cover the 'checked' section. If it's black and dirty drain and fill with 1000cc (1.1 qt.) 10W30 oil.

11. Take off the sediment bown on the fuel tap. Turn the lever to OFF. If it has a large accumulation of water clean out the old gasoline. If there's a lot of sediment particles the tank will need a good wash out with soap and water. Place a dab of grease on the rubber gasket so it seals best.

12. Take up slack in the throttle cable with this adjuster. There should be about 1/16 inch play in the cable to keep it from pulling the carburetor slide when the handlebars are turned side to side. Tighten the lock nut when adjusted.

175-350 BRIDGESTONE

Other than displacement, the 175cc and 350cc twins should be tuned by the same procedures. Check the service manual on your model for specs



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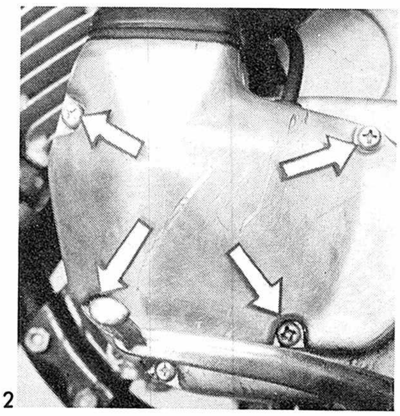
For the rider who cut his teeth on more conventional two-strokes, the twin-cylinder rotary valve engine holds a certain amount of awe. Many cannot comprehend how the operation of a rotary valve on each end of the crankshaft works. Having one valve per cylinder is the only way to do it naturally. With this method, the induction timing can be controlled, and you can get a little more out of the engine than you could a regular piston port design. The one disadvantage of the twins is the widening of the engine that comes from having to contain a carburetor on each side. On the 175 Bridgestone, both the right and left-hand sides look about the same, but you'll find that most of the tuning work is done on the left side. Calling for your attention on the opposite side are only one carb and the clutch adjustment. These machines are simple to tune and if the engine has not previously been taken apart, the average rider should have no problem. If the engine has been down before, and you find that you can't seem to bring the ignition into time, it is possible that the timing marks on the mainshaft gear, the clutch hub gear and the alternator gear were not lined up when they were reassembled. If this is the case, you will have to remove the clutch cover and line up the timing marks. The timing plug tool used here is a factory item that's very inexpensive to purchase; but if not available, you could make one easily enough by just drilling a hole in an 8mm bolt and inserting some type of pin.

1. Motorcyclist Magazine's own Tony Murphy campaigned a Bridgestone road racer with great success on circuit.



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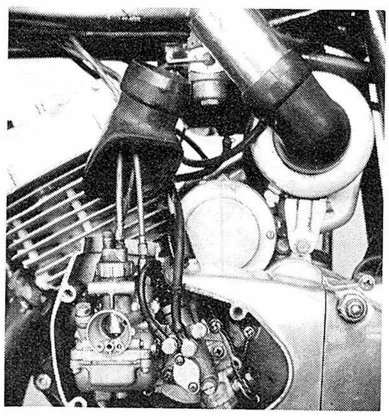
2. First, place the machine on the center stand or block it up so the rear wheel is clear of the ground. Remove the spark plugs so the engine may be revolved easily. Remove the four cover screws (arrows) on opposite sides of the machine. Take off both covers to expose the carburetors. The rear of the left-hand side contains the oil pump, while the right-hand side contains the clutch adjuster as well as the right carb.



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3. Lift up rubber carb cover. Slip out air cleaner tube. Swing tube out of way as shown. This is necessary for access to the ignition unit.

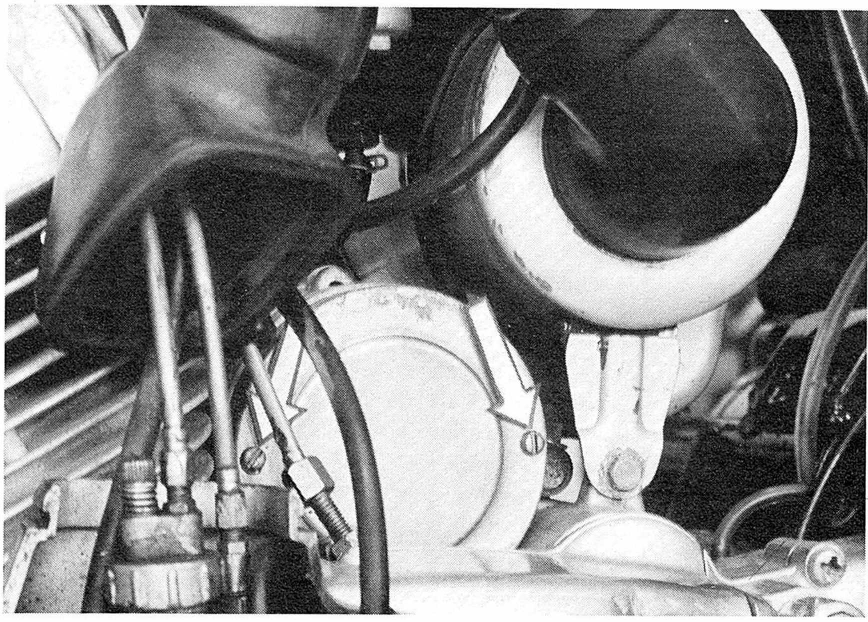
4. The contact points are mounted on the end of the alternator unit. First remove the two screws (arrows) which hold the point cover in position. Take off the cover. Thoroughly clean and burnish the contact points. If the contact points are pitted, they, as well as the condensors, should be replaced.

5. Rotate the rear wheel back and forth by hand and manipulate the gearshift lever until top gear is engaged. As this is a dual rotary valve model, each end of the crank drives a valve. This also means that the engine cannot be rotated with any degree of accuracy because of the carburetors on each side barring access to the crank. But, with top gear engaged and the rear wheel off the ground, the engine can be easily rotated by turning rear wheel.

6. Using the rear wheel as described in photo 5, rotate the engine until one set of points is fully open. Loosen the screws that secure the contact points and adjust the gap to .014–.016-inch. To adjust the point gap, lever the point base with a screwdriver by inserting it into the gap (arrow) provided for this purpose. Set the other set of contact points in identical manner.

7. At the front of the engine cases, just below the left-hand cylinder, is the ignition timing plug hole. As shown here, take a 14mm wrench and remove this plug. The orifice beneath extends right into the crankshaft assembly. There are timing notches cut into the crankshaft to accommodate setting the ignition.

8. Install the special ignition timing tool shown here. Just thread it into the hole; it doesn't need to be tightened down. The tool is just an 8x10mm bolt, drilled through the center to take the timing rod. You could make one easily enough, but the cost of the factory tool is low enough that you might as well invest in one; it'll be handy.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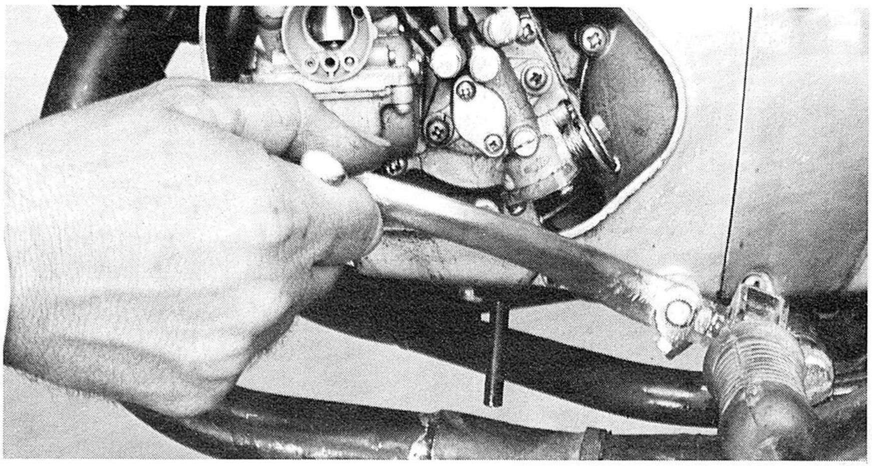
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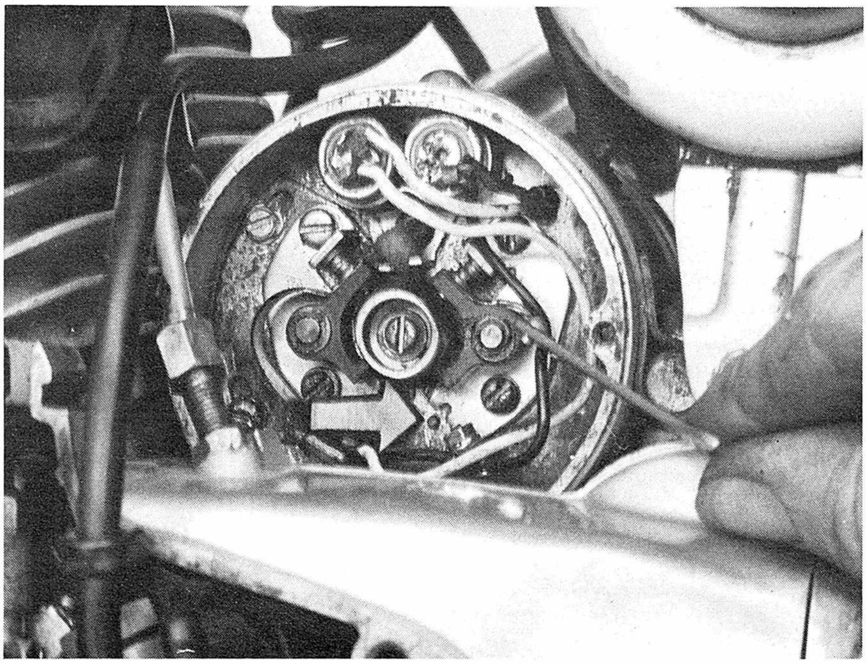
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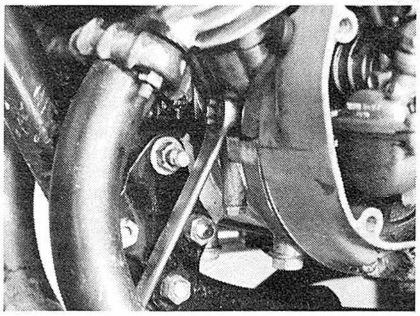
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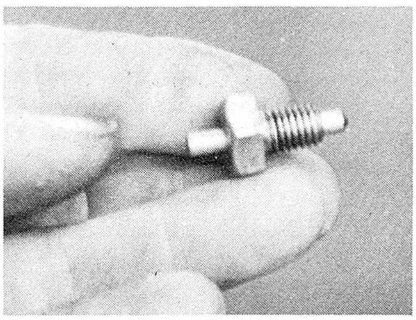
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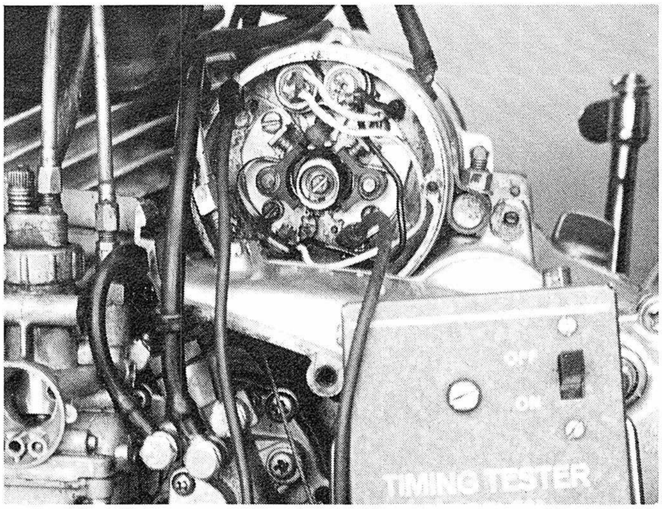

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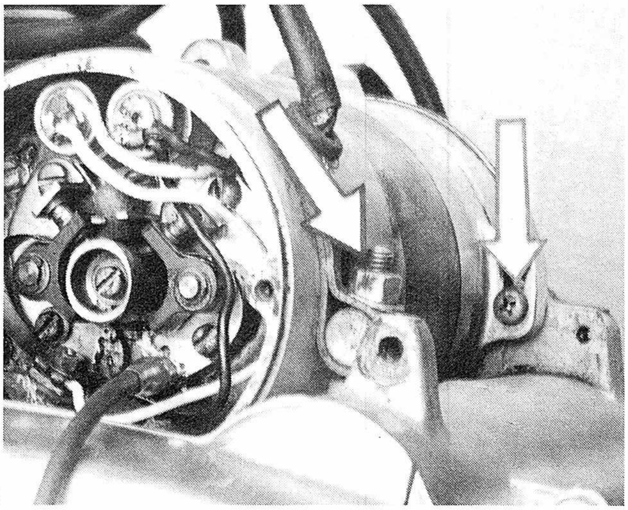
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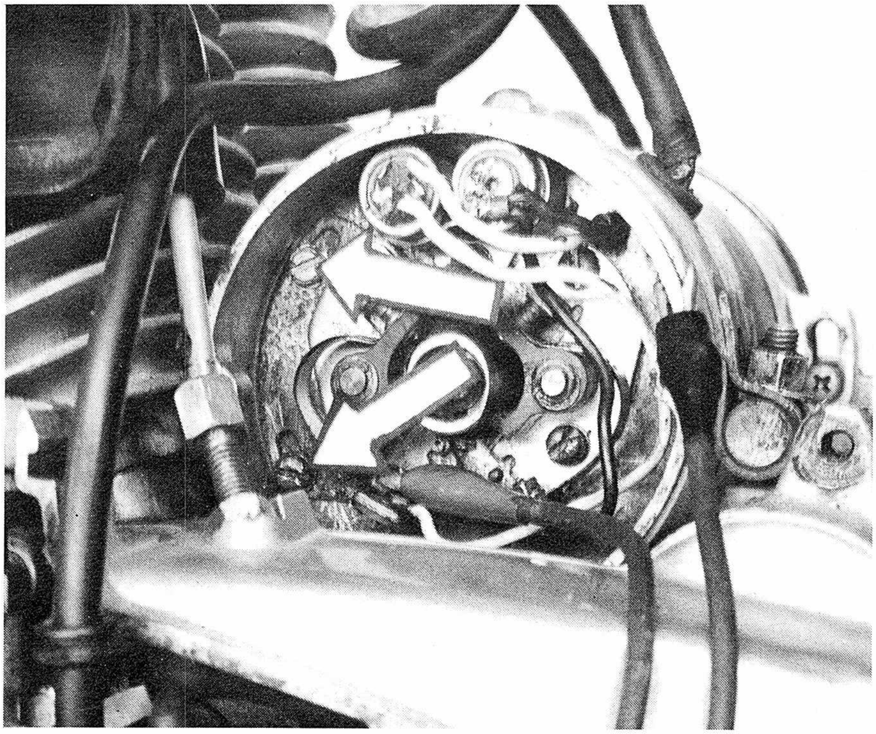
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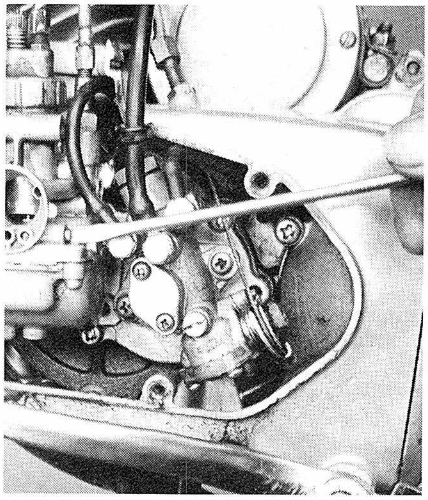
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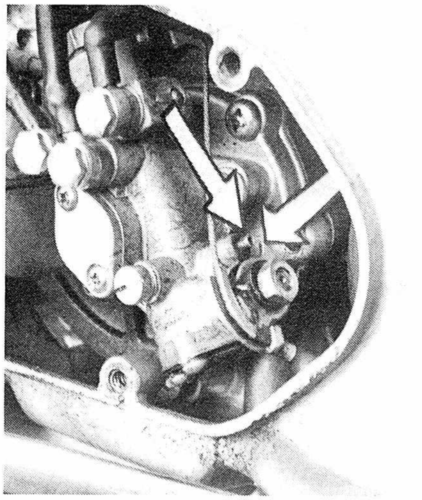
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9. Rotate the engine with the rear wheel until the right-hand set of contacts is just about to open. This means that the right-hand cylinder is just coming up to Top Dead Center. Connect one lead of the "buzz box" to the right-hand set of contacts and the other lead to a good ground.

10. Turn on the buzz box. Slowly rotate the engine forward while applying pressure to the timing pin with your finger. Just as the engine reaches the correct position Before Top Dead Center for ignition timing, the pin will drop into the notch in flywheel. At this precise moment, the buzz box should indicate that the contacts have just opened. If not, you must correct the timing by rotating the entire body of the alternator. Loosen the strap nut (front arrow) and the locking screw (rear arrow) and bring it into time. After tightening again, recheck the timing. Note: air cleaner's removed for clarity.

11. Repeat the positioning procedure for the left-hand cylinder with the left-hand contact points. To adjust timing on the left-hand side, it is obvious that the alternator cannot be rotated again. However, the left-hand points are mounted on an adjustable plate. Loosen the two screws (arrows) and bring it into time. Recheck after tightening screws. Caution: remove the timing tool and reinstall the timing plug.

12. Idle air screws are on the side of the carburetor as shown. Run into bottom and back out 1½ turns. To synchronize the carburetors, turn the throttle full open and grasp each throttle cable just above the carburetor. When you pull up on the cable, there should be no play in either cable while holding the twist grip at full throttle. Any play in either cable should be taken out with the adjuster located at top of carbs.

13. Next, adjust the oil pump. With the throttle closed, the space between the control arm and the pin stop (arrows) should be adjusted to ⅛-inch. Replace all covers and parts, and install new spark plugs. Fire up the engine and warm it up. When it reaches proper operating temperature, set the carburetor idle and you are ready to be on your way down the road.

PRESSURE CHECKING TWO-STROKES

A quick and easy test for locating those performance-robbing air leaks

BY DAVE HOLEMAN

The two-stroke motorcycle engine is indeed one of the simplest of engine designs. Conversely though, it is extremely sensitive to air leaks. The two-stroke is reliant on both pressure and vacuum in the combustion chamber as well as the crankcase chamber to run. The pressure provides combustion and forces the fuel charge up to the top end. Vacuum is necessary to draw in the raw fuel and air from the carburetor. While the combustion (cranking) pressure may be up around 150 psi, the crankcase vacuum/pressure will only be from three to six psi.

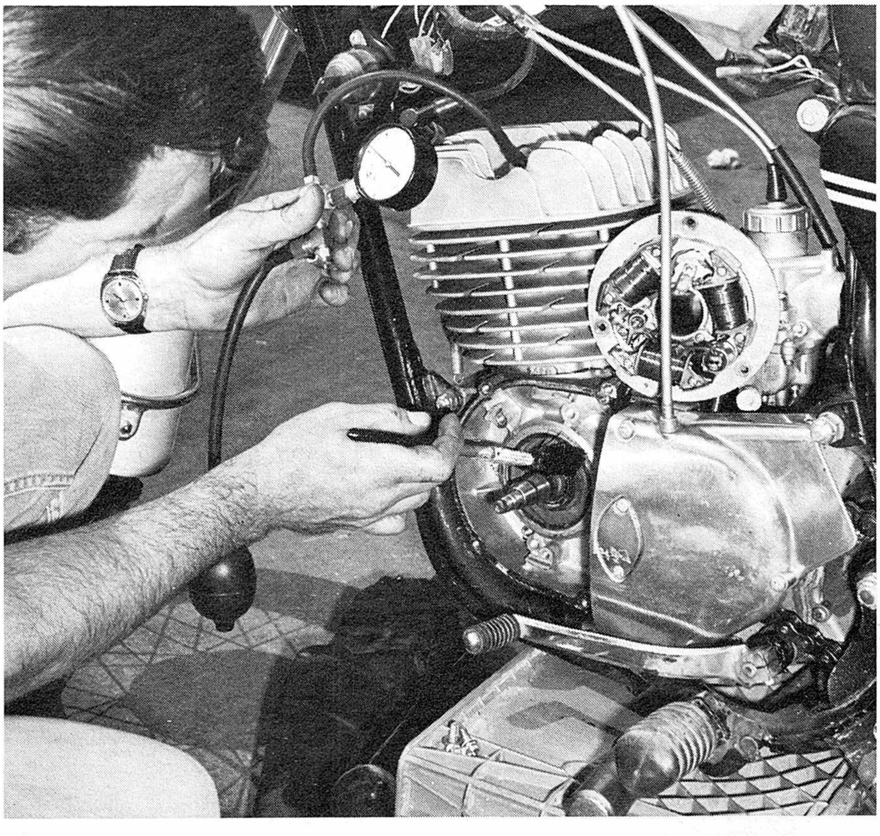
The pressure and vacuum figures are actually quite critical. Each particular engine is designed and engineered to run best at a certain cranking pressure and with a precise amount of vacuum/pressure from the lower end. The slightest variation from factory figures will result in poor performance that will become increasingly worse as the engine is run. The pressures and vacuum are controlled by airtight fits of the head to cylinder, cylinder to crankcases, case halves to each other and sealing of the protruding and revolving crankshaft ends. Other areas that must be sealed off to ensure maximum and trouble-free performance are the carburetor fit to the cylinder, spark plug seat, compression release (if you use one) and any oil injection fittings that your machine may have.

Briefly, what we are going to do is seal off the intake and exhaust port of the engine and fill the combustion and crankcase chambers with a slight amount of air pressure. Any leaks will be traced and sealed. We will perform this on a piston port engine (Yamaha Enduro) and a rotary valve powerplant (Kawasaki F8-250). With a slight amount of air pressure (only six pounds is necessary, more than this can damage seals or gaskets) inside the engine any or all seals or gaskets not providing an airtight fit will leak. Locating the leak can be done by ear or by applying some soapy water (liquid dish soap is best) to parts or areas that may not be holding pressure. Once the source of a leak is located, the cure is usually nothing more than a new gasket or seal.

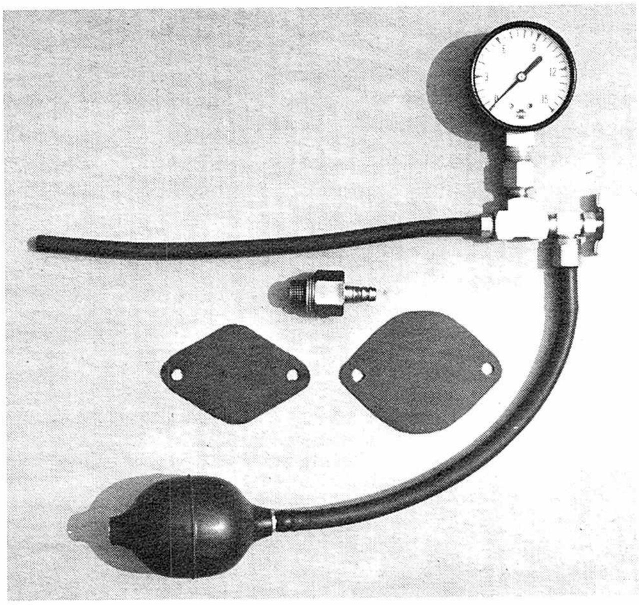
The type of bikes we used for testing are the ones most commonly plagued with air leakage problems. Single-cylinder dual-purpose or dirt bikes have by far the greatest problem with air leaks as compared to street twins or triples. This is probably because they are used more on a year-around basis and they are tinkered with more than street bikes.

Pressure checking street twins or triples is seldom necessary and involves having all the cylinders sealed off at the intake and exhaust to find any leaks. The cylinders cannot be checked individually as the labyrinth seal used between the individual crankcase chambers will not provide a seal unless the engine is running. Therefore should you desire to check a twin or multi you will need sealing plugs or gaskets for each cylinder although the single pressure and gauge unit is all you need. You simply have to pressurize all the cylinders which will occur as you pump up any one of them.

After installing the pressure checking kit equipment to the engine, the squeeze bulb should be used to pump up 6 pounds pressure, no more. Ideally the needle should maintain the six psi reading for six minutes. If you are testing a new engine, odds are it will hold. But if you're testing a used engine, odds are it just won't stay at six pounds for six minutes. A rule of thumb is that a good used engine shouldn't lose more than one pound of pressure in the first three minutes. Any good used engine will have a slight, very slight, pressure loss. The time when the engine definitely needs attention is when it loses any more than a pound pressure in the first minute. An engine that doesn't lose a pound of air pressure within the first minute but won't hold six pounds for three minutes is borderline and will naturally grow worse the more it's run.



PHOTOGRAPHY BY ERIC RICKMAN



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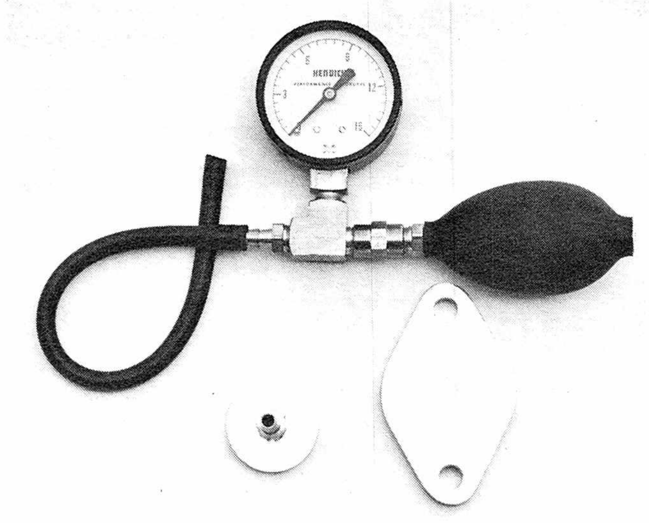

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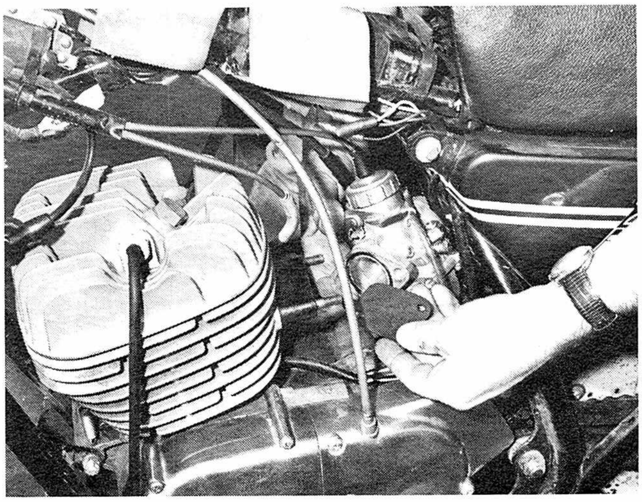

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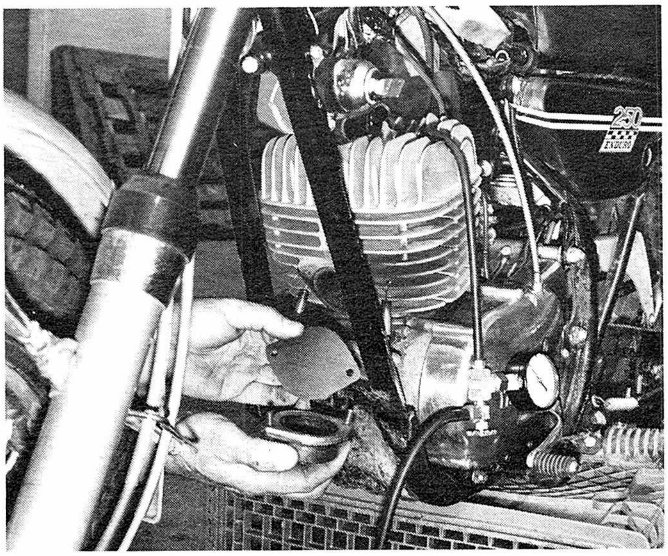

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So what does all this mean? If the engine won't hold air pressure it naturally has a leak somewhere. The next step is to locate the leak. Start from the top and work down. If the air leak is really bad you may likely hear it and be able to locate it by ear.

If the pressure drops, the first item to check is the testing equipment. Check the hose fittings and the intake and exhaust seals as these will leak if not cared for and installed carefully. Other things to remember are any particular engine symptoms that were apparent just prior to checking.

The first place to check is at the base of the spark plug(s) and if you have a compression release, there also. At this point it's time to bring out the can of soapy water mentioned earlier along with a small paint brush to apply it with. The object of applying the soapy water is that it will bubble where any air leak may appear making it easy to find visually.

If the spark plug or compression release leaks, first make sure they are properly tightened but not overtorqued. If this doesn't stop the leak, clean the plug hole seat and install a new gasket. If the leak still persists it's time to remove the head and have the seat(s) resurfaced by a machinist with a flycutter. If the compression release body leaks it may be time for replacement if the leak cannot be fixed.

Before you remove any engine parts continue checking for leaks as it's quite likely that there will be more than one. The next place to check is the cylinder head. This may require laying the machine on its side to permit application of the soapy water so you can make a visual inspection. Any leakage here means resurfacing the head and cylinder with emery and a flat plate and installing a new head gasket.

While you have the machine over on its side, apply the soapy water solution to the bottom of the cylinder where it seals to the crankcases. A leak here can lead to serious engine damage. Installing a new gasket and possibly machining the bottom of the cylinder should remedy any leaks at this point.

The only other exterior checks that can be made are the carburetor and manifold and any oil injection lines

1. The piston port kit for the Yamaha Enduro from Victor Products consists of a squeeze bulb, lines, air gauge, shut-off valve, sealing gaskets and spark plug filler spigot. Air gauge will show leaks as a pressure drop.

2. The Kendick pressure checking kit is like the Victor unit except this one has an automatic inline air pressure shut-off, ball check valve. Other parts for each kit are available for most all two-strokes upon request.

3. The first step in installing the pressure kits is to seal off the carburetor with the gasket or plate included. Don't overtighten bolts.

4. The exhaust port seal is next. Removing the gas tank makes things easier to get at. Install the spark plug filler firmly.

PRESSURE CHECK

that lead to the intake or lower end bearings. It's not unusual for bolt-on type carburetors to be warped from over-tightening. The same holds true for the manifolds. Surfacing them with emery on a flat plate and torquing to the proper specs cures this problem. With rotary-valve engines, the valve cover/manifold can leak where it fits to the engine or be porous. Not enough can be said about keeping a close eye on the oil injection lines and fittings. A loose fitting or banjo bolt can easily slip by the scrutiny of the best of mechanics. This also means checking the fittings at the oil tank as well the engine.

SYMPTOM	PROBABLE CAUSE
1) Hard starting, low compression or spark plug bridging	Poor spark plug seal Leaking head gasket Leaking compression release Porous head casting
2) Oily spark plug, unusual smoking, gearbox oil loss	Leaking crankshaft/gearbox seal Blown crankcase gasket or seal Porous crankcase casting
3) Sudden power increase, unusual power surging, pinging or pre-ignition, white spark plug reading, seizure or holed piston	Intake manifold leak Oil injection line air leak Loose and/or leaking crankcase seal Porous casting(s) Bad spark plug seal Defective compression release Leaking head or base gasket Blown ignition side crankshaft seal

Probably the most common air leakage problem is with the crankshaft seals. The crankshaft seals receive the lion's share of the responsibility of sealing, especially considering that they are subjected to continual wear from the spinning crankshaft. In fact, while going through the steps of pressure checking for pictures with Mike Harper at his Victor Products shop we found that the DT-1 Yamaha had a leaking magneto-side crankshaft seal. Though only a minor leak it would have led to serious engine damage in relatively little time.

Most all two-strokes will have one of the crankshaft seals (usually the clutch-side) retaining the crankcase pressure while keeping out the transmission oil. When this seal starts to leak the engine will not only suck in transmission oil, but it will also blow pressure into the gearbox cavity. Through a combination of oil being inhaled by the engine and lubricant being blown out under pressure, the transmission can be drained without the rider's knowledge. A dry transmission won't last long! Indication of clutch-side seal leaking is hard starting and poor performance combined with black, oily spark plug readings. In extreme cases the exhaust will smoke heavily. If no exterior leaks can be found and the engine won't hold pressure it's possible that this seal is bad. During the pressure testing tests remove the transmission oil filler cap and listen for any gurgling in the oil indicating a pressure leak into the gearbox cavity.

While the engine will begin to start and run poorly when the transmission seal is gone, the magneto-side seal can produce entirely opposite results. The magneto-side seal will suck in air from the vacant area in the ignition cover and blow out some fuel mixture

1. Now pump up the squeeze bulb until the gauge reaches six psi, no more. Too much pressure can damage seals or gaskets. A well sealed engine should hold six psi for six minutes. A loss of one pound in three minutes is a borderline case. Losing more than a pound per minute is a bad leak.

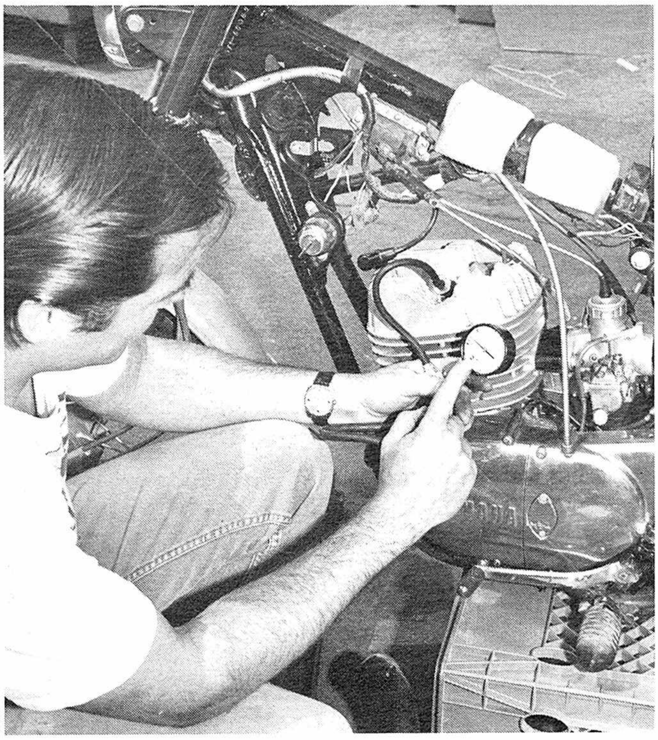
2. If you have a leak, check the kit fittings first by ear. If you can't pinpoint the leak, apply soapy water to any suspected area. A leak will show up as bubbling soap suds. If this doesn't show any leaks lay the machine on its side and apply soapy water to the head and base gasket areas for air pressure leakage.

3. Commonly the leak will be the crank seals which can often be detected by ear. Gurgling sound indicates a leak.

4. To ensure that the leak is a seal, apply the soapy solution to the crank seals directly and watch for bubbles.

5. Kit for the rotary valve Kawasaki engines is complete and fits all single cylinder models. The installation is about the same except there is no spark plug removal as pressure is pumped through the exhaust port.

6. It may take three hands to check the rotary valve engine as the intake sealing cork pops out easily with full pressure. It's important to scrutinize for possible porous rotary valve castings. While the side covers are off, make sure the oil lines are tight.



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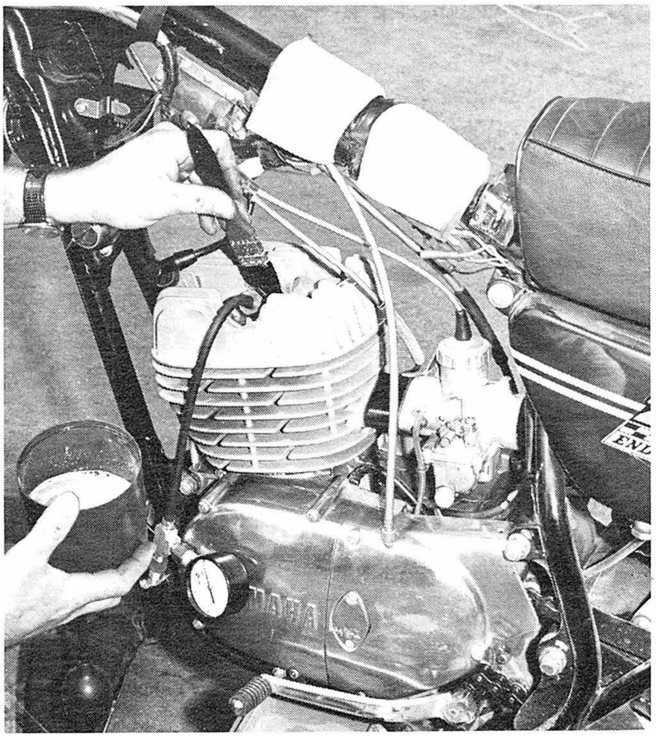

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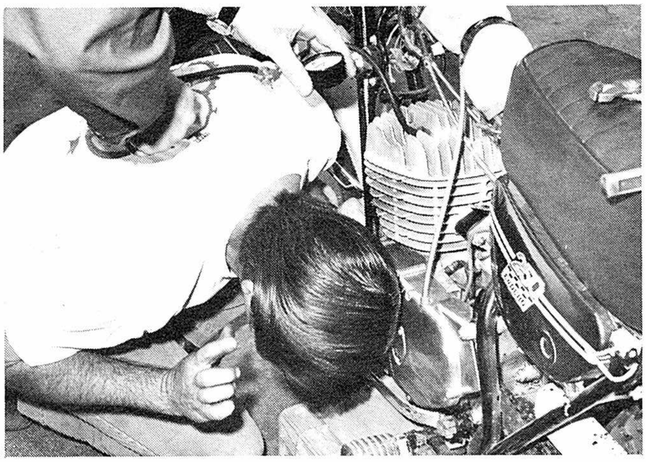

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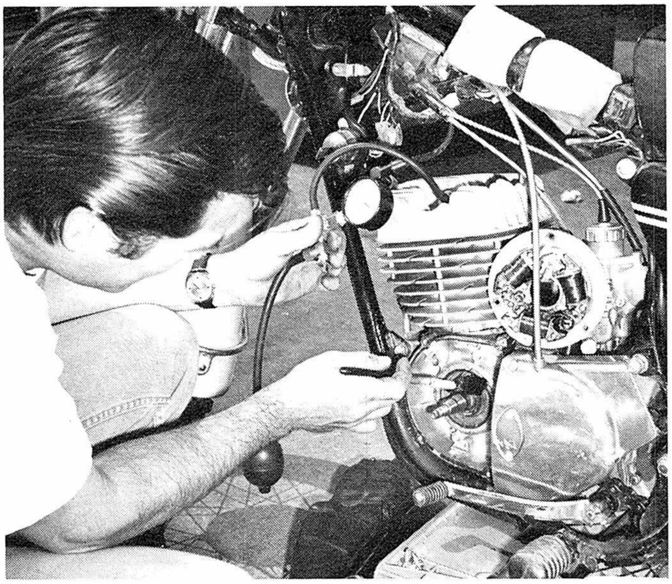

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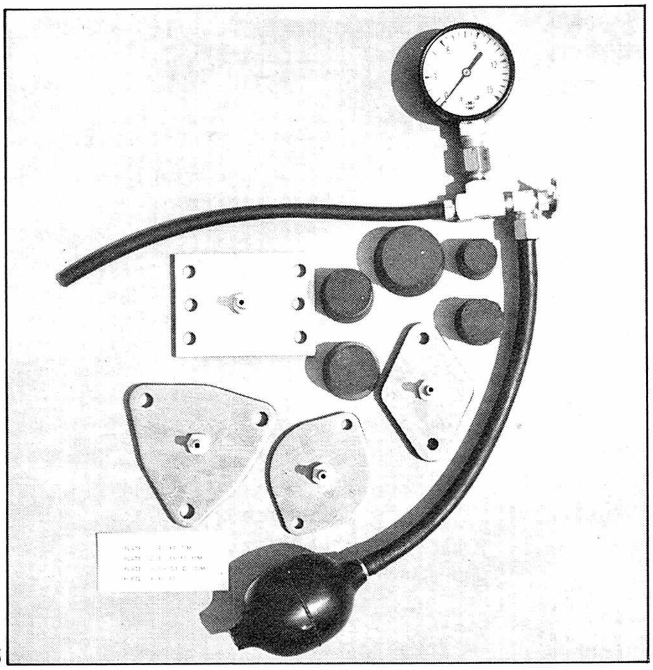

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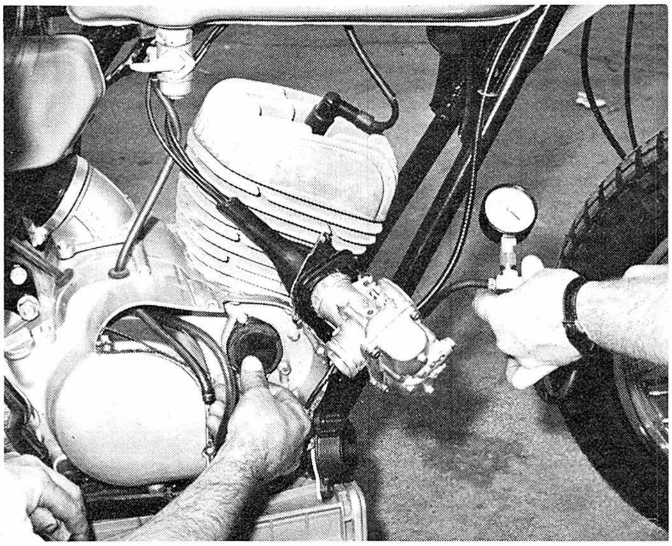

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also. When this seal goes or begins to leak the performance may increase due to the leaner fuel/air mixture. Accompanying this in later stages, pinging and pre-ignition may occur which indicate extreme leaning of the fuel/air mixture. This can be further verified by unusually white spark plug readings all of which will certainly mean engine seizure and/or a holed piston in some cases (including our Yamaha DT-1) the leak on this side of the engine can be detected by ear along with visual signs of fuel (oil) leakage into the magneto area.

In some cases the crankshaft seals can be replaced without disassembling the engine, but generally it means removal and splitting the cases to install new ones. Needless to say, if one seal is gone the other is probably about due so it's best to replace both while the engine is apart, along with other seals and gaskets.

The only other source of air leaks is from porous castings, though it is unusual. This is usually the most difficult leak to find. If all of the aforementioned checks have been performed and the cause for the engine not holding pressure can't be found, only one step is left. At this point it's time to pull out an old washtub and fill it with a soluble liquid (cleaning solvent or kerosene is best) and immerse the complete engine assembly. Just like checking an inner tube in water for a puncture, any leaks will immediately appear as air bubbles coming to the surface. In extreme cases, leaks such as porous castings have to be located in this manner. If you're lucky, a porous casting can be cured with a quick heliarc weld. If not, casting replacement is necessary.

All of this may sound like a lot of time or a lot of work, but this is seldom the case. As we found out during the testing procedure with the Yamaha DT-1, the location of the leak was found in just a matter of minutes by listening and using soapy water. Fortunately in this case the DT-1 seal could be replaced from the outside so replacement was also quick and easy. For any two-stroke, particularly dirt bikes that are a year or more old, it's probably about time to check and be sure the engine is airtight. A few dollars and less than an hour's time can save you the cost of a complete engine rebuild. The Victor pressure checking kits are available from your local Yamaha or Kawasaki dealer. The Yamaha piston port kit is around \$17.00 depending on the model and type of machine. The Kawasaki, rotary valve, kit is around \$26.00 and fits all their single-cylinder models. The Kendick (Chatsworth, California) pressure checking kit is for piston port machines and runs from \$12.00 to \$18.00 per kit depending on make machine and can be ordered from your dealer or obtained by mail from Kendick. The cost of any one of the kits will pay for itself many times over each time you locate a leak.

MAJOR ENGINE TUNING

Don't give up on that old bike—give it a new life

BY BILL OCHELTREE

Feelin' down in the dumps 'cause Old Faithful is letting you down lately? Maybe it would be nice to get a new bike, but the bread is a little short these days? How about the thing down the street? It's been in the guy's garage for two years and he only wants $250 for it. Looks alright but sounds like it's going to fall apart? Well take heart, things aren't as bad as they may seem. A trip around the world is no reason to go to the junk heap, it's only 25000 miles. Somebody else's miseries could be your pleasure. Here's the ticket: as long as it runs, has all the gears, and looks like everything is there, chances are that a major tune-up will make it just like new. Give it a try!

Major tune-up is type of work falling somewhere in the realm between minor tune-up and complete overhaul. This chapter will deal in more than just the engine, though. Actually, what is involved could be called a major "inspect/repair as necessary." That's old Air Force jargon more commonly referred to as IRAN. It means going over everything on the vehicle to see that it's in good working order. This is something that should be done about once a year whether or not you think it needs it; you'd be surprised at how many things wear or get out of adjustment, but that you're unaware of because they've happened gradually. Of course all these things have their limit, and when they finally do give out it seems that it's always at a bad time, and at the maximum distance from any help. The best way to be prepared for trouble is to go out of your way to avoid it, so instead of worrying about what might go wrong get busy and find out!

As we say throughout this book, you have to have the minimum equipment by way of tools and facilities for any job, and neatness and cleanliness are important too. The tools you'll need for a major tune-up aren't very elaborate and a lot of make-shift goodies can be put together from bits and pieces that have been laying around. A basic hand tool set is, of course, essential, along with a few feeler gages and some 'heavy' type automotive tune up gages (available at Western Auto or the like for a paltry sum). If the bike is caked with mud, grease or a few years of neglect, gunk it, de-grease it, steam it, wash it and perfume it: we won't touch it

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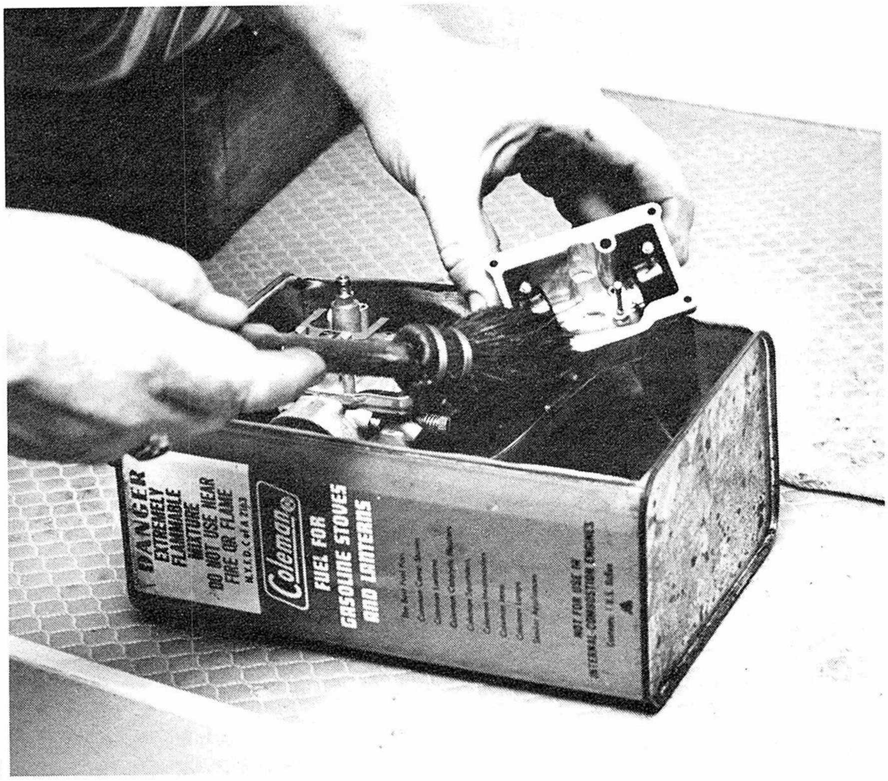

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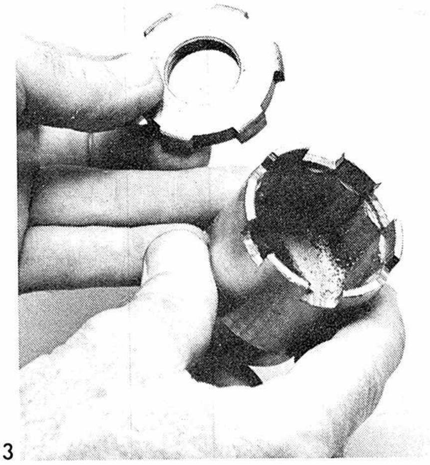

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1. About one evening a month is all the time needed to keep your bike in top condition. A clean, well-equipped shop is a definite asset.

2. Parts cleaning is an art that can be practiced with much make-shift equipment. Here is a gallon can with a side cut out. Be real careful with flammables! Don't use gasoline or other fuels, and NO SMOKING!

3. Special tools can be improvised in many ways. Often a standard tool can be modified to do the job. This wrench for a crank nut was milled from a large socket.

til it's clean! You're going to need a few road maps too, so hustle down to the dealer and get the service manual, owner's handbook, parts books, and any other publications that have plenty of pictures of the particular model you have. You can never have too much information. Now that everything's ready, let's go to work.

Most of the subjects covered in this chapter are treated in great detail in other chapters of this book. Also, there just isn't enough room here to tell you eveything about your bike so you'll have to do some digging in the service manual. What we'll do here is outline the things to be done and refer you to other chapters or your service manual, and we'll elaborate on some things that aren't covered elsewhere and show you some 'hot set-ups'.

A real thorough going-over of your bike can get pretty involved. Let's break it down to get a clear picture of what we're going to talk about. We'll break this up two ways: types of work to be done, and major components and systems of the bike itself. Let's break it down further so you can see the line of thought here:

TYPES OF WORK

a. Cleaning
b. Teardown/assembly
c. Inspection
d. Repair/replacement
e. Paint/finishing/lubrication
f. Adjustment/tightening/securing

MAJOR COMPONENTS & SYSTEMS

a. Engine/fuel/oil
b. Intake/exhaust
c. Drive train
d. Wheels/brakes
e. Suspension
f. Frame
g. Controls
h. Electrical/instruments

CLEANING

Cleaning methods and techniques are many and varied; each having its best application and some being very special. The alchemists of yore called water the "universal solvent" and that it is; it's a great cleansing agent and also a good corroder. Dont' get that wrong, a good bath is the best thing you can do for a bike at regular intervals, provided the water is kept out of critical areas and the drying out process is hastened. A do-it-yourself car wash of the hand-held nozzle variety is the easiest way to clean your bike. The engine exterior and wheels are a snap and its about the only way to get into all those nooks and crannies in the frame and underneath. Be careful around the carburetor air intake, ignition parts, instruments, exhaust pipe, chain and brakes. Water in these areas can mean trouble. This is a good method for cleaning a caked-up chain but it must be run immediately to throw off the water and then well oiled. A brief ride to warm up the engine and dry out the brakes is recommended after any wash job. Don't confuse the car wash type gun with a commercial steam cleaner; the soap used in the steam cleaner will take the hide off an elephant, whereas car wash will only take off mud, oil and road film and leave the paint intact. If you don't have access to a car wash, the old bucket of suds and a large toilet bowl brush will have to do, followed by a rinse with a garden hose.

A really tough engine de-greasing job will require one of the water soluble degreasing solvents sold at most auto supply stores. These require extra care because they contain strong alkalis which convert greases into soaps that can be rinsed with water but which will eat away at just about anything including paint, aluminum and your body. Be real careful with these, follow the instructions on the can and rinse well with hot water.

A good all around solvent is a petroleum by-product called 'Stoddard Solvent.' This is similar to kerosene but does not leave an oily residue and is easily rinsed with water. The next best substitute for Stoddard solvent

is ordinary paint thinner, not turpentine or synthetic enamel thinner; they can really gum things up. *Warning: fuels such as gasoline, kerosene, naptha and benzene are very dangerous and should not be used.* The reason for this is that these have low flash points. The flash point of a flammable liquid is the temperature at which the quantity of the fumes given off by the liquid forms an explosive mixture with the surrounding air. For these fuel-type liquids the flash point is near ordinary room temperature and the least amount of spark or flame can set them off. For this reason use only high flash point solvents or thinners and then exercise caution. If you have a water heater or furnace in the garage, move out into the driveway to do any cleaning. Those fumes are heavier than air and can get pretty deep along the floor, and a pilot light is just the thing to raise the temperature enough to start a fire. Stoddard solvent is available at most gas stations under that name or as 'cleaning solvent.'

Pans and brushes for cleaning are available at most auto supply stores or as a make-shift, a large roasting pan or refrigerator pan will do. Always store cleaning solvents in closed metal containers for safety. Covered coffee cans are handy for storage and are convenient for small cleaning jobs.

One other handy cleaning agent that must be used very sparingly is lacquer thinner. This is best for preparing surfaces for the application of cements or 'stick-ons.' Apply only with a cloth and then wipe immediately with a clean, dry cloth. Be very careful on painted surfaces and plastics; try a test spot first.

TEARDOWN & ASSEMBLY

This is a subject that nobody gives much lip service to, but everybody has given some thought to at one time or another. Thoughts like "What did I do that for?" or "I guess I should have done that first before I tried to do this," or "I could have sworn that thing took five screws, where does this one go?". Moments like this are the result of just plain poor planning, and the frustrations and wasted time could easily be saved by giving a little forethought to the job. Things like special tools, work stands, bench & vise, something like an anvil to hammer on, cans, boxes and shelves to store loose parts and all of the things that go to make up the "compleat shop" are easy to come by if you just keep your eyes open. Getting the most done with the least amount of work is a matter of studying the job and staying awake while you're at it.

First of all don't skimp on the removal of things that get in the way. When diving into a big job on a motorcycle, the tank and seat should be the first things to come off. Be careful where you set the tank, if there are any exposed threads on the fuel line fitting, protect them from being dinged up. Things like carburetor, oil tank and battery should come off if they can possibly get in the way, and they should be protected from the entry of any dirt or foreign particles with suitable plugs, covers or tape. If you are going to do any electrical work, at least disconnect the battery, it could save the charge along with avoiding burning up wiring. As you take apart complicated assemblies, store the parts in their own container to avoid mixing them with something totaly unrelated. This will greatly speed things when putting them back together. One last word on this subject: don't ignore the shop manual. If they have a recommended procedure for doing something, it's probably the best way.

INSPECTION

This is another field where staying awake, along with a lot of horse sense and some experience, will pay dividends in having to do the job only once. Careful examination of everything on the bike is sort of a detective game. Just the appearance of something can give you clues to impending trouble, or where some unseen trouble lurks. A lot can be told about a bike prior to taking anything apart. Oil leaks; loose, & sloppy or rough and jerky operation of controls; noisy gears, chains or bearings; these are sometimes thought of as normal for many motorcycles but they are only indications of careless assembly, or shoddy maintenance, or just plain old age. Things *are* supposed to work smooth, quiet and clean; don't believe any excuses to the contrary.

When tearing things down an eagle eye should be kept out for any evidence of wear or the presence of unwanted dirt or particles. Measurements of course should be made to determine whether or not some parts

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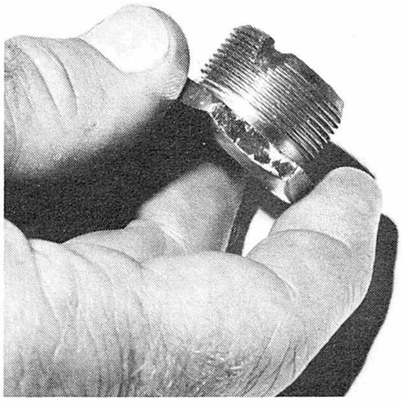

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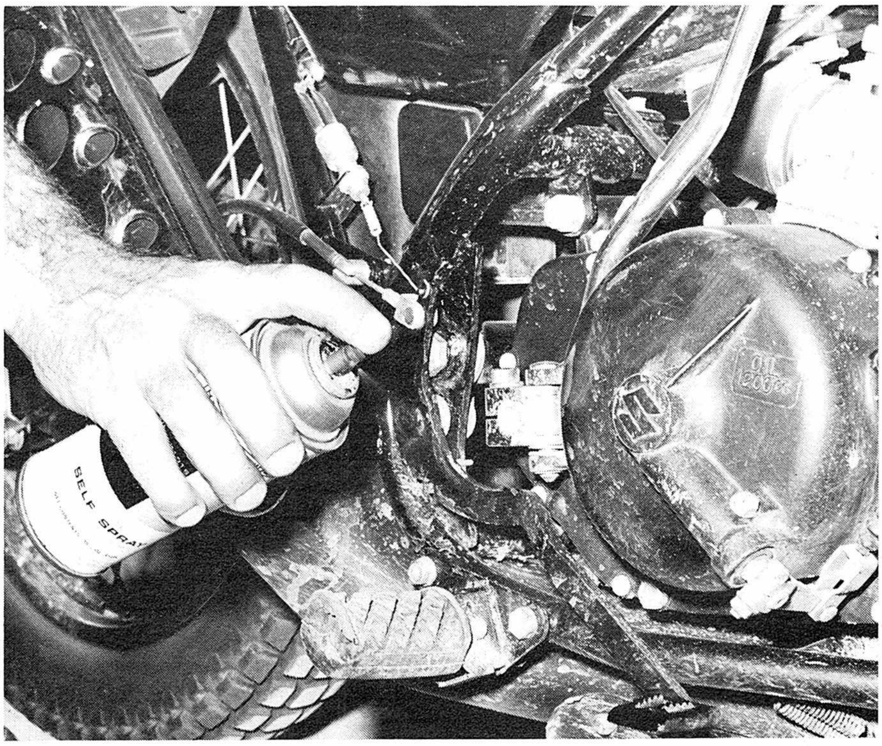


have gone beyond reasonable limits of wear. Here again the right tools make the job easier, but a lot can be done with the simplest of devices. In any case, the lack of something like a micrometer is no excuse for not somehow doing the job. Feeler gages are very inexpensive and can be used for many precision measuring jobs with a little ingenuity.

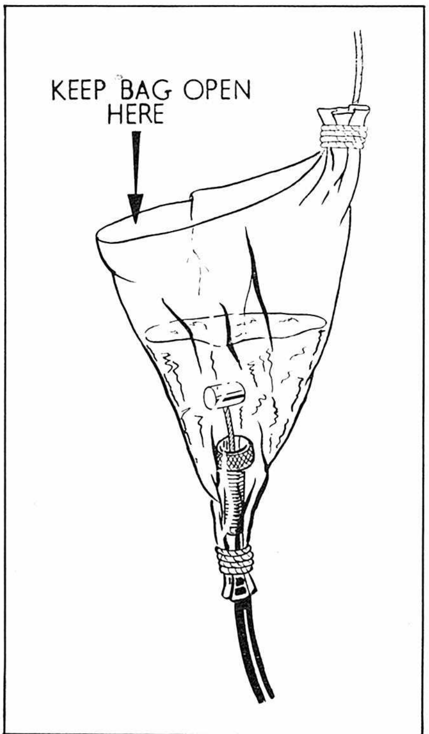
REPAIR/REPLACEMENT

Here is where sound judgement based on knowledge and experience comes into play in making decisions concerning the wisdom and economics of either making do with something of doubtful quality, applying practical techniques for the restoration of worn or damaged parts, or completely replacing it with a new one. We'll try to cover this in more detail when discussing the different types of bike parts and hardware, and when in doubt there's no substitute for the experience of someone who's done the same thing before. Don't be afraid to ask and keep in mind that the cheap and easy way out now could cost you more later.

1. The top plug on the front forks can be ground like this to clean up bad threads. It can still be used as a plug, too. Apply heavy grease when using it, to catch chips.

2. Touching-up worn and sand-blasted areas on the frame will prevent rusting and keep your bike looking 'sanitary.' Wash it first, and wipe it down with thinner before painting.

3. This is an age-old trick for keeping cables smooth as silk. Disconnect the lower end and put a can under it. A light engine oil will run through overnight.



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PAINT/FINISH/LUBE

Virtually all materials used in the manufacture of familiar things require a protective coating of some sort. Most people consider that these coatings are primarily for the purpose of enhancing the appearance of things, but in actuality, they are necessary for the preservation of the materials from the destructive effects of nature. There are a few exceptions to this in plastics and some aluminum alloys, but generally speaking 'what you see is *not* what you get." The paint, plating and brightwork on the bike make it look nice of course, and you probably want to keep it looking good, if not out of personal pride, certainly from the standpoint of resale value.

Don't consider finish from the standpoint of appearance only, the unseen areas are the ones that can cause trouble from the standpoint of safety and reliability. Climates with high humidity and rainfall can generate a lot of rust on unprotected steel, and salt air will raise havoc with aluminum and magnesium. Water will often easily find its way into closed areas and then become trapped and begin to perform its insidious habit of helping the air to eat away at everything it comes in contact with.

A good example of this is in the rear wheel swing arm pivot. If you ever have to replace the bushings in that area, you will probably find that a large drift pin and a very heavy hammer are required to remove the pivot bolt or shaft. The parts will seem to have been welded together with rust and the inside of the swing arm crossmember will look like the inside of an old water pipe. Aside from nickel plating the whole thing to prevent a repeat, a good scrubbing with a wire brush, a coat of zinc chromate or lead oxide primer and then assembling everything with a second coat of primer while it is still wet, is the best way to slow down the rusting process. A hole drilled in the bottom of the crossmember will admit water when the bike is running through deep stuff but it will also provide a drain for all the water that might get in there from any point.

Nuts and bolts are also a good example for the requirements for a protective finish if you have ever had to remove an old rusty, unplated one. The cadmium and zinc plating used on modern fastenings has cut into the sales of penetrating oils and if you don't want to do the "soak and wait" routine, then make sure to replace those that are on the verge of rigor-mortis.

Parts that slide or turn within each other won't hold a finish very long so the next best thing to preserve them and to make their operation a little smoother is lubrication of some sort. It's amazing what a little bit of oil or grease can do to something that seems to be on the verge of seizure. Every moving part on the bike requires lubrication of some sort and even the latest trick Nylon and Teflon bushings can go to pot pretty quick in the presence of dirt and grit.

Here's a brief list of the minimum supplies you should have on hand to accomplish basic touch-up and lube:

—Primer: A small spray can of zinc chromate or lead primer. "Rustoleum" makes a good variety of these.

—Touch-up paint. Black lacquer in

ENGINE TOP-END CHECK LIST

HEAD

De-carbonize
Check for warp, look for gasket leaks
Check valve guides and springs
Lap valves

VALVE TRAIN

Check cam lobes and lifters for scoring, galling
Check push rods for straightness, ends for wear
Check rocker arms & shafts for wear, lubrication

CYLINDER

Top ridge
Taper
Scoring
Base leaks
Two-stroke port clean up

PISTON

De-carbonize
Ring grooves
Sand scuff marks
Measure skirt wear
Ring end gap
Wrist pin fit

ROD

Pin fit/bushing
Crank side clearance
Big end up-down play

a spray can is ideal for keeping the frame looking new. If yours is another color a close match can usually be found.

—Chain oil: The foam spray motorcycle chain lubes are good for all around use, and in a lot of water the industrial chain and cable oil that looks like asphalt is a mess to put on, but it won't wash off!

—Grease: No shop should be without a can of sticky old grease to hold things in place and maybe even be used on something like a bearing once in a while. The best general-use type for these purposes is a marine or boat trailer wheel bearing grease.

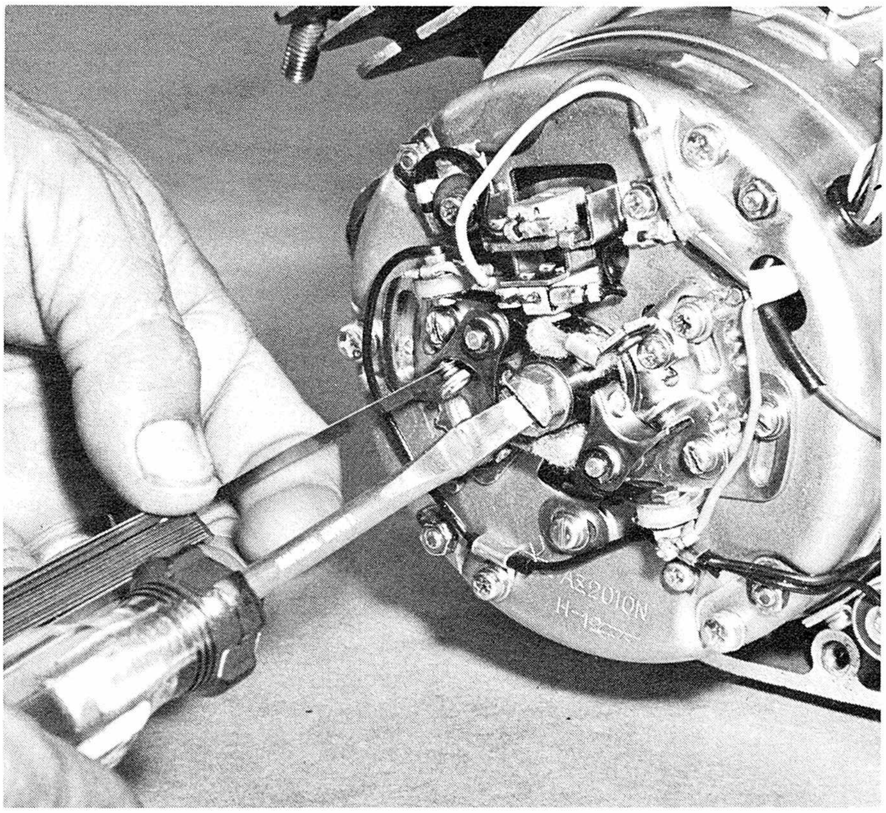
—Oil: Don't forget the trusty oil can. Drippings from motor oil cans are an endless free source to keep an inexpensive squirt can full.

—Special lubricants: Small amounts of these will last a lifetime and are indispensible for certain jobs. Molybdenum disulfide is superior to graphite for a dry lube and is available in powder form or as a paint-on. A high-temp grease such as 'Lubriplate' is a must. A lightweight penetrating/lubricating oil such as 3-IN-1 or WD-40 comes in real handy for those real sticky ones.

ADJUSTMENT/TIGHTENING/SECURING

These are either the most ignored, neglected or forgotten things that contribute the greatest amount of anxiety to the average motorcyclist. Just about everything in any sort of mechanical assemblage requires some periodic attention to its condition and appropriate action to either restore or maintain it in its proper state. When ignored, neglected or forgotten the gremlins arise to bring about faulty operation, no operation at all, or possibly failure or complete loss of the parts involved.

Adjustment is involved in many functions of the motorcycle. Here is a handy check list of adjustments that should be made periodically. Your owner's manual specifies different periods for most of these and may not mention some of them, but in any case the heading implies that about once a month you should at least consider the list and make appropriate adjustments according to your own personal needs and experience.



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30-DAY CHECK LIST

Points
Timing
Valves
Carburetor—air, idle, float, needle, synchronization
Oil injector/pump
Cam chain
Primary chain
Clutch
Rear chain
Front brake cable
Clutch cable
Throttle cable
Choke cable
Compression release cable
Gear shift
Rear brake pedal
Rear brake rod/cable
Stop light switch
Brake actuating arms
Steering head bearings
Headlight aim

Other points, not strictly adjustments, demanding equal attention:
Tire pressure
Air cleaner
Exhaust mufflers
Battery water
Oil—engine, gear box, primary

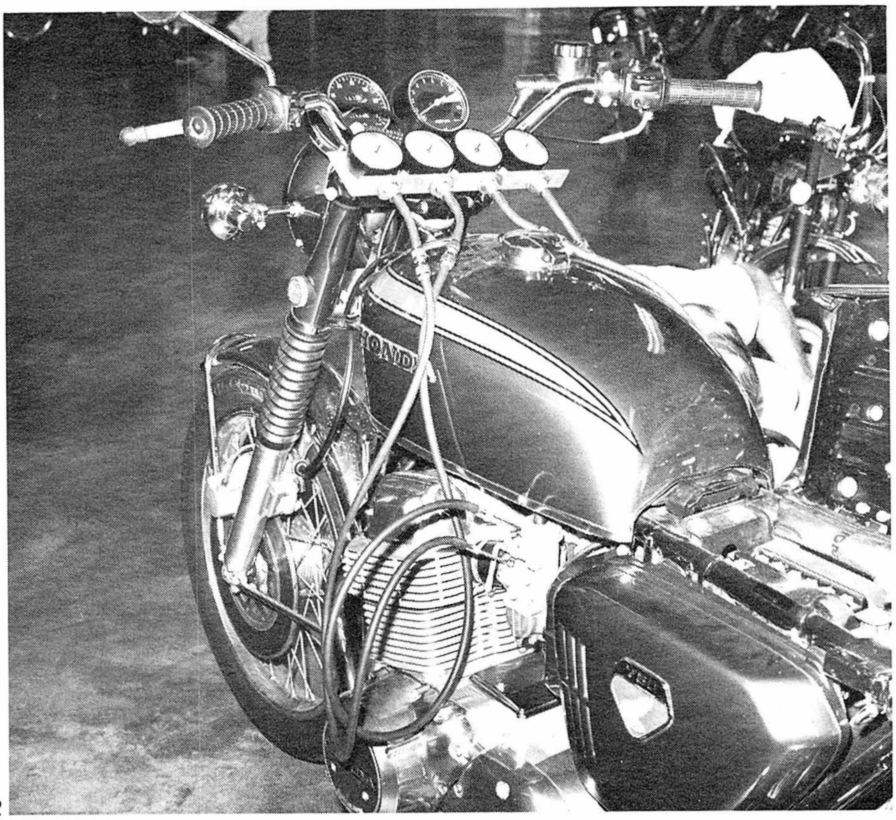
The subject of tightening applies to every nut, bolt, screw and threaded device or fastener on a motorcycle. Anything that you can put a wrench or screwdriver on should be checked at least twice a year. The vibration that exists in the operation of a bike is much greater than normally found in most vehicles, and this can cause many problems that only constant attention can avoid. A new bike should be completely gone over within its first week of use, and then followed up about a month later with another tightening, and then another a month after that! Anything loose on that last exercise must be considered for either safetying or replacement with something that will hold. Important points to take note of immediately are: axle nuts, swing arm bolt, steering head, handle bars, control levers, engine mount, foot pegs, drain plugs, and most important and needing continuous monitoring are the wheel spokes. These are the primary safety items and worthy of more than just a casual glance.

1. The ignition system is the heart of the engine and should be kept in sharp tune. An occasional drop of oil on the wick will slow down wear. Too much will foul the contacts.

2. Carburetor adjustments on the big multi's can get pretty involved, but the effort can be worth it for super-smooth operation. See 'Minor Engine Tuning' for a way around this set-up.

3. A neglected centrifugal advance mechanism has caused many puzzling tuning hang-ups. See that yours is working free and give it a little 'Lubriplate' to keep it that way.

Tightening brings up the question of: how tight? Our chapter titled



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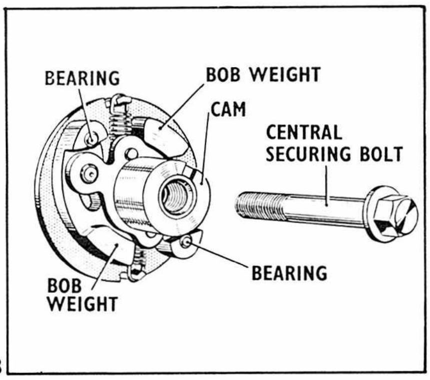

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"Specs and Formulas" has a listing of recommended torque values for various structural-grade bolts. The grading symbols are not always on the bolts so the values given must be considered only as a guide, and the manufacturer's recommendations for special fastenings, especially in the engine and gearbox, should be closely followed. Impact and torque wrenches are valuable items for obtaining proper tightness, so have a look at the chapter on tools; it will give you a good idea of what is needed. When it comes to small bolts and screws the only torque measuring device available is your wrist, so be very careful if you don't want to suffer skinned knuckles and exasperation.

Securing and safetying methods vary depending on the type of fastener, its application and the degree of safety required. The lowly lockwasher is the most common form of securing device for nuts and bolts and is found in nearly all installations. When the lockwasher doesn't do the job then more drastic steps must be taken in the form of locking tabs, self locking nuts, cotter pins, bonding resins such as Loctite, external seals like 3M 8001 Weatherstrip Cement, or safety wire. We'll note the application of these various methods as we get into the details of the bike.

ENGINE/FUEL/OIL

Now that we've covered all the preliminaries, let's get down to the nitty-gritty of the bike itself. The biggest single thing and the source of most problems is the engine. In doing a tune-up as such, the only things to be covered here are those which can be done without removing the engine from the frame. Check into the appropriate chapters on engine rebuilding, carburetion and tune-up for the details of the things that we'll point you to.

Let's assume that you have an engine that's running but doesn't seem to perform like it should. A minor tune-up is what you should have done first to make sure that all the usual fine points had been covered. If the engine is still misbehaving, then you will have to look further. The two most likely places to find trouble are the ignition and fuel systems.

Everybody likes to diddle the adjusting screws and pull off the air cleaner, but nobody likes to dig into the innards of the carburetor for fear of losing some of the parts. Ridiculous! You may have been snowed at some time by the fearsome looking guts of a four-barrel Rochester but a motorcycle carburetor is about as complicated as changing the overhead lights in the bathroom so get with it.

The first thing to look for is dirt. Pull the float bowl off the carburetor and the sediment bowl off the tank and be careful to not spill anything; you're looking for clues. Pour the contents into a light colored, shallow container and keep an eye out for blobs of water and rust scale. Water may be the result of a careless wash job or a night in the rain, but it may also be in the gas you've been buying, so check into the tank to see if there's any accumulation. Rust scale or other solid particles can give all sorts of intermittent running problems so anything more than a couple of specks would indicate that the entire fuel system needs cleaning.

Carefully drain the tank into a proper gas can and then remove it from the bike. Pull all plugs, petcocks and caps and turn a high pressure stream of water into the tank and try to dislodge as much loose matter as possible. Drain and shake the water out and if compressed air is available this will help to dry it out. A rinse with alcohol will also soak up moisture, and the best thing is a day in the sun to thoroughly dehydrate it. If you want to use the gas that was drained from the tank, strain it through a chamois when pouring it back.

A good cleaning of the fuel supply system may cure a lot of problems, and a great accumulation in the tank and lines will also mean something is probably making a home in the carburetor itself. A carburetor rebuild isn't very difficult if you follow the instructions and keep things clean and orderly. Be sure to check the jet, slide and needle sizes against the service manual specs if someone has had the bike before you. Some guys seem to have a talent for tuning things into a complete botch by changing jets and adjustments without really knowing what they are doing. Don't forget the float setting when re-assembling the carb. It's easy to forget but can make a big difference.

Of course you have set up the ignition system to perfection, but have you checked out these items? If the

ignition has an automatic advance, the point cam should be able to rotate freely on the shaft within its limits and the springs should return it solidly to the retard position. A little high temperature grease like 'Lubriplate' is just the ticket here. If you're using flywheel marks to set the timing but something tells you it's not quite right, better check it against the piston position with a dial indicator. Sometimes those marks can be off enough to really louse things up. If the bike starts and runs alright when cold but then gives up and quits after it's warmed up only to be alright again after cooling down, you may have a bad ignition coil. Get it tested or borrow another one and try it. Badly burned points are a symptom of a bum condenser, but sometimes the points themselves can be defective. If no immediate improvement is seen after dressing the points with a tungsten file then chances are that's where the trouble lies.

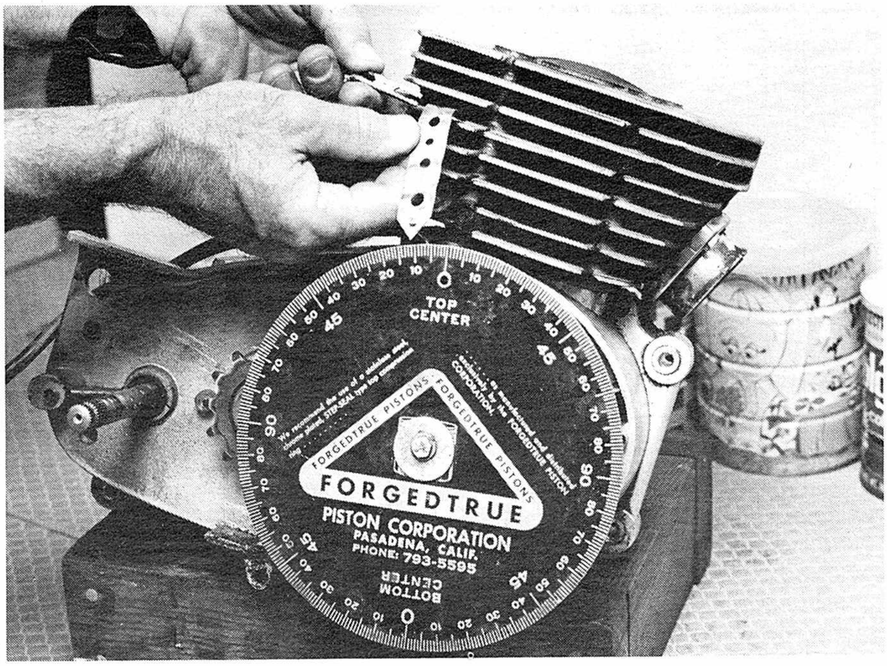
Let's back up now to the basics of the minor tune-up. A compression check should be the first order of business and if you have obtained low readings (100 to 125 psi is borderline depending on compression ratio; anything below 75 psi is zilch) it will take more than a clean carburetor and hot ignition to make that engine put out. Rings and valves are the things that hold the air in, so if it's not pumpin', you'll have to start humpin' on a top end job. With a two-stroke you've got it made. Just pull the barrel and give it a bore and/or ring job. The chapter on two-stroke engine rebuilding will show you how to check the piston and cylinder bore with feeler gages and clean up the piston just like new. With a four-stroke the valves may have to be re-seated by lapping them in, just as you would after a re-grind. If an engine is in a condition where cylinder boring and valve grinding or replacement are required, then consideration should be given to a complete rebuild, which will put you beyond the realm of major tune-up.

Whether or not an engine needs a complete rebuild depends on its age, mileage, type of service and care. If you know the engine or its previous owner, you can probably make pretty good judgement as to its condition. If you aren't familiar with the engine history, you'll have to do some detective work once you've pulled the top end off. Even if you know the bottom end is OK it wouldn't hurt to spend a little time to make sure. We've included a check list of things to do or look for when doing a top end job.

ENGINE OILING

The engine lubrication system is probably the most taken for granted yet vital part of the bike. Without oil the engine not only doesn't run very well, but it can cost some big bucks to fix the damage incurred. Changing the oil just isn't enough if you use the bike anywhere outside of a dust and moisture free environment. That eliminates just about everywhere and the amount of crud that builds up in the oil system is just a matter of time depending on how much off-road riding you do. Two stroke lubrication is a fairly straightforward way of doing things; the oil is burned almost immediately after it is used. The only hooker here is that nothing can be taken for granted. YOU better remember to put oil in the gas on your primitive pre-mix scooter and keep the tank full on the 'mix-it-as-you-ride model or you'll be in the same fix as the guy with a broken oil line on his Triumph.

The two-stroke oil injection systems are simple enough to check out, and most owner's manuals have instructions for checkout and adjustment. Passage of the oil through the system is strictly a one-way affair, so there shouldn't be any dirt accumulation if you have been somewhat careful when filling the tank. Just the same, it wouldn't hurt to take it off now and then and wash it out with solvent. Although pressures in the system are low enough to preclude leaky fittings, the hoses can deteriorate with age, so make sure they are in good shape. Four-stroke engine oil systems are the ones that are taken for granted as long as there is a reading on the dip stick. This is alright for a while but the nature of the system is such that metal chips, dirt and sludge are recir-



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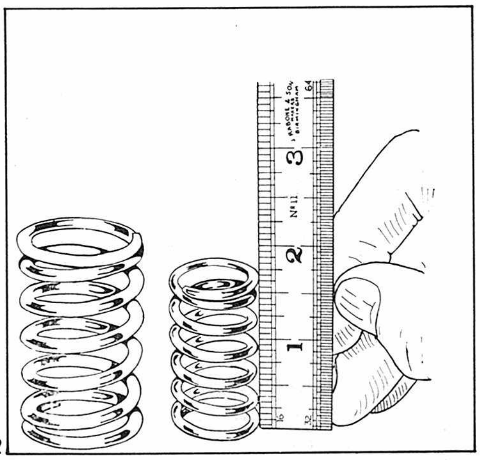

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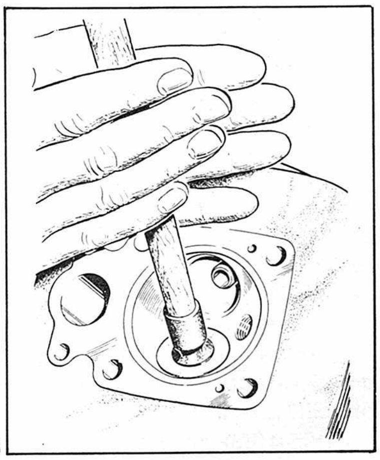

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culated through the system and eventually find places to accumulate and block the intended flow path for the oil.

Four-stroke oil systems fall into two general categories: wet-sump and dry-sump. Wet sump systems are found on all but the rarest of automobile engines. The oil is carried in a large reservoir at the bottom of the crankcase where it can provide a continuous bath of cooling and lubrication in addition to the pressure feed directed at crank and cam bearings and up to the valve rocker shaft. Most motorcycles use the wet-sump system with the notable drawback of combing engine lubrication with gear box and clutch. The main disadvantage of this is that metallic particle accumulation takes place at a greater rate than separate engine lubrication and the manufacturer's recommendations for oil change interval should be closely adhered to if reasonable engine life is to be expected.

1. A degree wheel is a must for checking timing marks or valve timing. Make sure it's firmly tied to the crank, and a pointer can be easily improvised.

2. Check valve spring lengths against factory specs or compare them with new ones when doing a top overhaul. Weak springs will cause poor sealing and allow valve 'float' at high speed.

3. Re-seating the valves will assure a perfect seal for maximum combustion efficiency. Lapping compound and suction cup tool are available at auto parts stores.

4. Clean up the head and lightly polish it with emery paper. Smooth off sharp edges of plug threads to prevent pre-ignition-causing 'hot spots.'

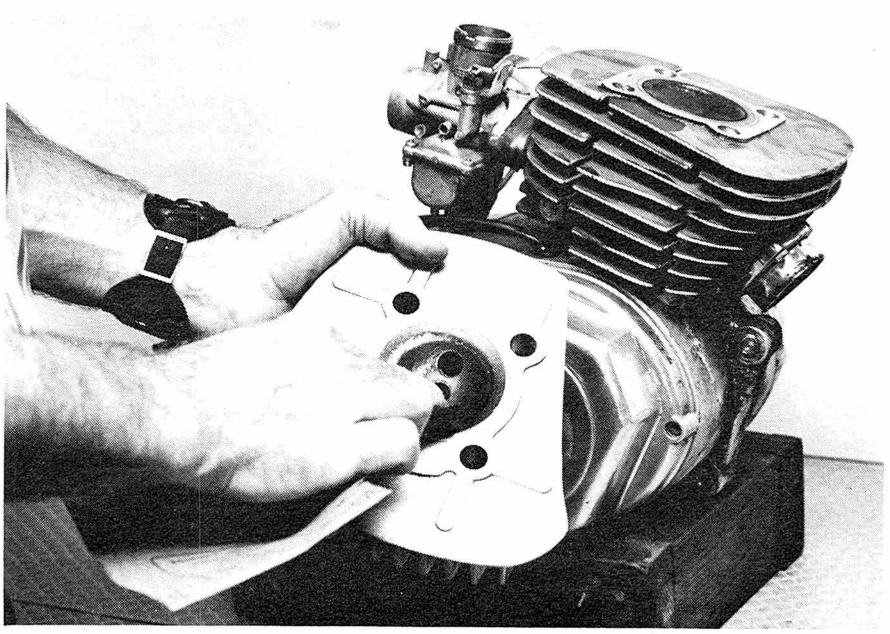
In addition to regular oil changes, the things to be watched with these systems are the screens, filters and traps that are built in to intentionally trap unwanted bits and pieces. These should be cleaned out at the first couple of oil changes on a new engine or fresh rebuild and about every third oil change thereafter. Some engines (just about all Hondas) have a centrifugal filter which spins the oil as it passes through and forces heavy particles to its outer periphery where they pack in and stay until cleaned out. This should be cleaned out annually and instructions can be found in the shop manual. Some of the new models come equipped with automotive-type paper filters which should be replaced at the recommended interval. The shop manual will usually give instructions for checking oil pump operation and this should also be done at your annual check-up session.

Dry-sump systems are patterned after the aircraft philosophy of keeping the crankcase as small and light as possible and then finding a convenient place to stow the oil in a lightweight tank. This is a universal practice on all British bikes and is the exception to Honda's wet-sump policy in their 750-Four. In these set-ups, the clutch and gearbox have their own oil supplies so that eliminates one source of contamination. A necessary requirement for the dry-sump system is a dual pump lash-up. Half of the pump supplies high pressure oil for bearing and valve lubrication and the other half scavenges the expended oil from the crankcase and returns it to the oil tank. The oil tank is generally a two to three quart container located under the seat area, and the latest wrinkle from England is to incorporate the oil reservoir as an integral part of the frame structure as in the latest series of BSA and Triumph bikes. The separate tank and pump arrangement require suitable connecting plumbing and check valves to prevent the oil from seeping into the crankcase when the engine is idle. This complicates the system and brings on another source of contamination. As long as the engine is operated to maintain uniform temperatures (long trips or warm climate) the oil stands a pretty good chance of doing its job for a reasonable length of time. The external oil system has pretty good cooling capacity and short trips in a cool climate make for pretty high moisture accumulation and a consequent formation of sludge in the tank and lines. You may think you're running your engine in the best of conditions but unless that oil gets heated up enough to dry out, you're no better off than a desert racer.

Whether it's a wet or dry sump engine, taken for granted it shouldn't be, wet sump systems should be flushed regularly, depending on conditions, with a 50-50 mixture of light oil and cleaning solvent. There are usually screens installed in the tank and scavenging pick-up and the cleaning schedule described above for wet-sumpers should be adhered to. The external feed and return lines should also be checked regularly for fitting security and flex hose condition. If your engine has been running strong and has good compression, but suddenly there is a rash of oil consumption accompanied by a smoky exhaust and wet breather spray, you're 'wet-sumping.' If this happens only when you first start the engine and then clears up, it's probably the return line check valve letting oil drain from the tank to the crankcase overnight. If wet-sumping conditions persist while the engine is running, you've got a bum scavenger pump. The shop manuals describe all the necessary maintenance and test procedures for the dry sumpers, so take heed and they won't give you any unwanted surprises.

INTAKE & EXHAUST SYSTEMS

Here are two more items that can bring no end of grief to the unwary. The symptoms of a sick intake or exhaust are similar to the symptoms of



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other illnesses, and after all kinds of tuning and troubleshooting you can be tearing your hair out 'til some wise guy comes along and tells you it's a plugged air cleaner or exhaust. As in everything else, care and maintenance are the only things that will prevent trouble in this area so don't overlook them.

Air filter cleaning or replacement requirements vary widely with the type of filter and operating conditions. Paper filters are the type that general purpose and touring bikes are most often equipped with. These are actually the finest grade of filter and will provide a very long service life under normal road conditions. Being capable of stopping very fine particles makes these filters subject to very rapid clogging under extreme dust conditions and will require frequent replacement. The blotter-type nature of the paper used in these filters also makes them vulnerable to moisture of any type.

The basic symptom of a plugged air cleaner is the inability of the engine to operate at full throttle; it's as though the choke were partially closed and when the throttle is opened to match the choke opening, no more air can flow but the fuel will continue, making for an extremely rich mixture. A paper filter will show this phenomenon immediately after having run through water deep enough to wet it or after being inadvertently hit with the hose during a washing. About all that can be done under these circumstances is to nurse it along at part throttle until the filter dries out. After about a hundred miles in extreme dust conditions, a paper filter will begin to behave like it is wet. The symptoms come on gradually at first and as the surface becomes completely caked the engine will barely run at all.

Paper filters may be re-conditioned by gently rapping them to dislodge heavy surface dust and carefully blowing from the inside with compressed air. Don't use a real strong blast of air or you'll tear the paper, and never use compressed air on a wet paper filter, it'll blast it to shreds. Reconditioning of this sort may be done several times before the surface of the paper becomes so impregnated with fine particles that it loads up after a very short time. Another application of the dry paper filter that has proved to be very unsatisfactory is on pis-

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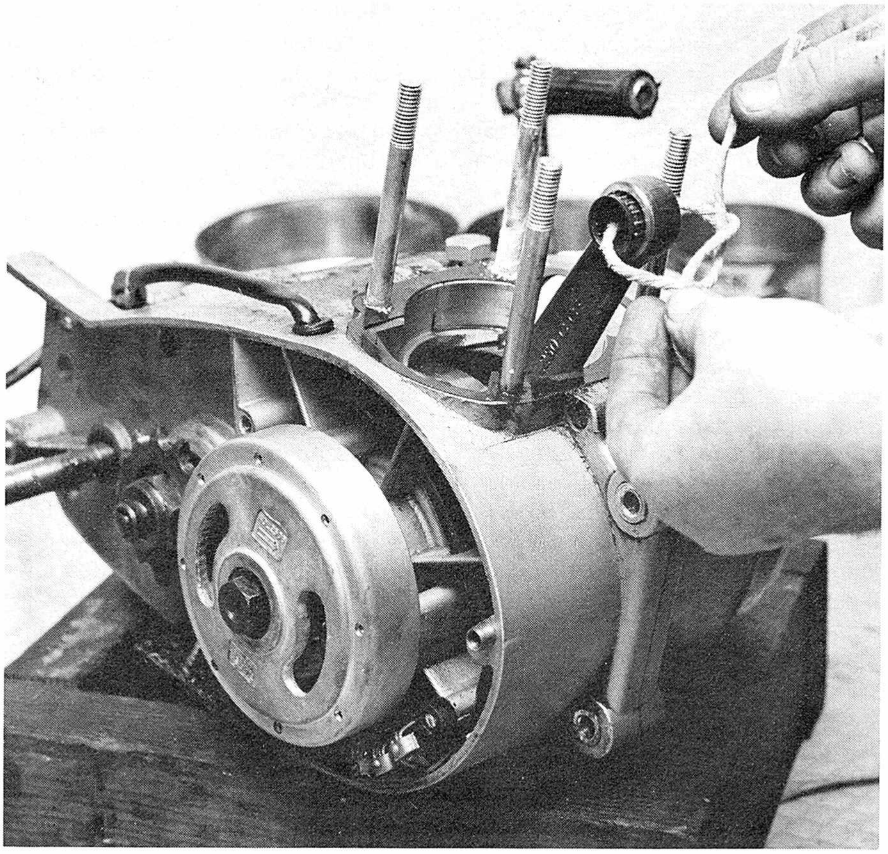

ton-ported two-stroke engines where the filter is in close proximity to the mouth of the carburetor. In this case the spit-back spray from the carburetor leaves an oily wetness on the inside of the filter which will bring about complete saturation in a fairly short time and render the filter completely useless.

This brings us to the wet-type foam or felt filtering element. These are not only ideal for piston-port two-strokes but find wide use in all types of off-road and competition bikes because they will last much longer in heavy dust conditions and may be washed and re-used indefinitely. Rather than rely on 'screening' action to keep out particles as the dry-type filter does, the wet filter performs an 'entrapping and retaining' action to hold the fine particles. The porous foam filters are of the 'depth loading' type wherein the particles actually penetrate the foam to a depth of around .10 to .20 inch. As the inner compartments become filled with dust particles the entrapment proceeds outward to the surface until the filter begins acting as a 'face loading' type. Contrary to some belief, the foam filters do not require cleaning after every ride, but are capable of operating at full capacity for several hundred miles. As long as the filter element has a damp appearance on the surface it is

1. A simple piece of string can do much to prevent problems. You can always be sure parts will go back in the way they came out if you use string on them instead of your finger.

2. When checking piston wear, measure the skirt diameter in several locations. Vernier calipers like this cost about $25 and are about the best investment you can make.

3. When checking the cylinder, measure both top and bottom to determine taper. A heavy ridge at the top will also indicate the need for a re-bore.

operating as a depth loader. When large, dry powder areas begin to show, then the filter is going into the face loading phase of operation and will require servicing within a short period.

The wet felt filter is a compromise between the face loading dry type and the depth loading wet type. It will operate for a short time as a depth loader but because of the finer texture of the fabric it will become a face loader much sooner. Its greatest advantage over the other types is that it is virtually unaffected by water. The dry paper filters are badly affected by water and the foam types will show some affect for a short time if drenched, but the felt type are the best compromise under combined conditions of both dust and water.

The proof of the operation of any

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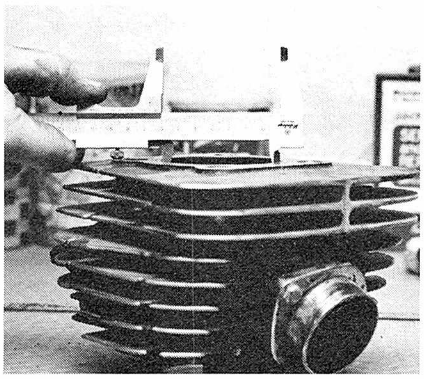

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filter is what it looks like on the inside after a long period of use. When doing a major or minor tune-up or during routine maintenance on a strictly dirt bike, the filter should be carefully removed so as not to disturb the evidence, and examined on its inside surface and at the points where it makes contact with its housing. The inner surface of the filter element should look like the outside of a brand new element no matter what conditions it has been run in. Areas of dark brown blotches are evidence of where water has hit the filter and been drawn through. If the entire inside looks like this, you need better shielding around the filter. The surfaces where the filter contacts the housing may show a little dust around the outer edges, but the inner side should be clean with no evidence of dust having gone through. A look at the inside of the filter housing and down into the intake pipe should reveal no dust whatsoever. Shine a flashlight in there and look for leakage at any hose joints also.

Cleaning of the wet-type filters is accomplished by thoroughly rinsing in cleaning solvent, drying by shaking or blowing the felt type and squeezing the foam type and then oiling with the heaviest engine oil available. Squirt the oil on the felt filters and dip or squirt the foam ones and squeeze the excess. When possible allow the elements to stand overnight in a pan to let excess oil drain, otherwise immediate use may result in a smokey exhaust and possible plug fouling, almost like wet or plugged filter operation. The reason for using heavy oil is merely to prevent 'migration' of the oil to the housing and on to the garage floor; light oil will help trap dust as well as heavy but in warm weather or over a long period of time will drain off and lose some effectiveness. When re-installing the filter element in its housing, a coating of thick grease at the contact points will help to insure a good seal and prevent any leakage around the edges.

The exhaust system on a bike is something that will go a long time before it will show any signs of trouble. Actually on an engine that is kept up to its peak operating level at all times the exhaust system should last forever. The main constituents of the exhaust gas are carbon dioxide and water. The carbon dioxide is harmless (not so for carbon monoxide) but in long exhaust systems that don't get a chance to thoroughly warm-up, the water vapors will condense and bring about rusting from the inside. This is what happens to Grandma's car that hardly gets used but needs a new muffler every year but doesn't happen to Uncle Joe and he puts on 50000 miles a year. This is one problem that seldom occurs on a motorcycle. The exhaust system is short enough that even a short trip will allow enough time to heat all the plumbing and keep it dried out.

The major problem encountered on bike exhausts is the accumulation of oil on the two-strokes or on a heavy oil burning four-stroke. The multi-cylinder two strokes with large mufflers for small cylinders are the ones most likely to cause trouble. The temperature required to burn off oil is much higher than that required to boil off water and the small cylinders of the multis just don't put out enough heat to raise the temperature of those big shiny mufflers. Consequently, over some period of time the baffles in the mufflers will become caked with a hard coating of carbon and tar and the holes will begin to close up. The symptom here is a generally ratty running engine and a very smoky exhaust. About once a year is a good time to dismantle the mufflers and give them a good cleaning or even replace the baffles with new ones. About the only way to clean two stroke mufflers that look like they have been paved with asphalt on the inside, is to burn the stuff off with an acetyline torch and then scrub them with a wire brush.

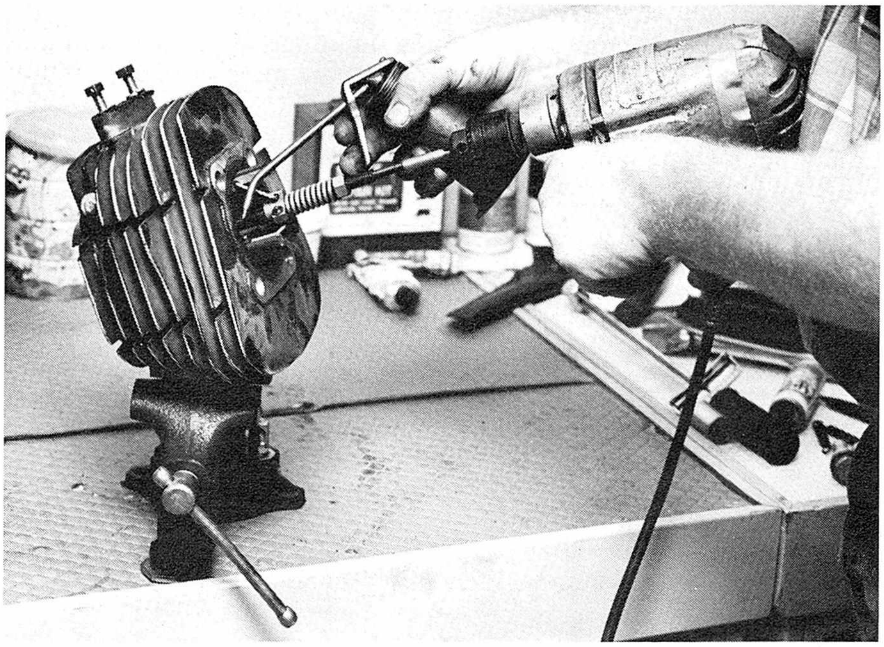
The causes for a badly 'coked-up' exhaust lie in the type of oil used, the fuel-to-oil ratio and the type of riding. Read Pepe Estrada's chapter on 'Lubrication: 2 Stroke & 4 Stroke' to get some idea of what to expect from various types of oils and make sure your injector pump and control are set properly to achieve the right mixture. Your service manual will tell you how to do this. As far as the type of riding you do, long, high speed touring will result in less oil deposits than just cruising around town. If your pipes seem to plug up more than necessary even with everything in good tune, try enlarging the holes in

the baffles by drilling them out about 1/32" larger. Don't go too big or you'll be ticket-bait for excess noise; it's amazing how a little bit bigger baffle hole will go a long time without clogging and won't increase noise or alter engine operation. Don't overlook the exhaust ports and the first few inches of pipe on both two and four-strokes. These can become caked with residue while the rest of the system is fairly clean and the reduction in size can rob you of quite a bit of power. Make sure the valve is closed or the piston is over the port while cleaning; that stuff won't do any good in the cylinder.

Leaks in an exhaust system can cause erratic running, backfiring and possible overheating in any engine, so be on the lookout for oil or soot at the ports and pipe joints. When installing the exhaust pipe, put a new gasket at the port joint and re-tighten all the joints after running for a short while. Make sure all the mounting points are in good condition and securly fastened, otherwise you may be buying a new cylinder if the exhaust port won't take the weight of the whole pipe. Some exhaust ports are notorious for having pipe connections that won't stay tight under any conditions so keep an eye out for yours and safety wire them if necessary.

DRIVE TRAIN

The drive train consists of the primary chain or gears from the engine to the clutch, the clutch itself, the gearbox and the final drive chain, or shaft, as the case may be. The chapters on 'Clutches and gearboxes' and 'Chains' will be a good guide for repair and maintenance of these vital components so we'll go through just a brief refresher here to hit some of the high points. Although motorcycle gearboxes are of the constant mesh type, they are not true 'synchromesh' and therefore they generate a lot more metal particles to grind away the gear teeth and bearings than do automotive gear boxes. For this reason gearbox oil should be changed about once a year on bikes used exclusively for touring, twice a year for city bikes, four times a year if you're a clutchless shifter or off-roader and about once a month for bikes used in track racing of any form. These are minimum suggested frequencies and if your owner's manual recommends changes more often or you feel a little



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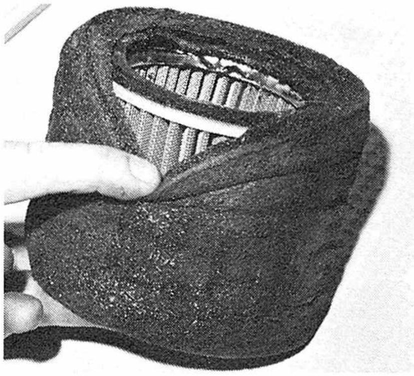
uneasy about it, do it! Oil is cheap.

Separate primary chain cases should have their oil changed about as often as the gearbox and special attention should be given to the drippings for any evidence of broken chain rollers. The primary drive cover should be removed about once a year anyway to check the condition of the clutch and chains should be checked for wear at the same time. Some people advise against it but when it comes to automatic transmission fluid (ATF), consider that it does a pretty good job with clutches and gears that carry a helluva lot more power at higher temperatures than in a bike. One thing for sure, you'll never have a sticky clutch with it.

Once you've ridden a bike for some time it's very easy to get used to all its little idiosyncracies, but if you really want to see a difference in the way a gearbox can shift then dig into the service manual and find out exactly how to adjust the shift mechanism and clutch, and guaranteed, you'll have a slicker shifter than a brand new one. Be careful in adjusting the clutch to be sure there is some clearance between the clutch operating mechanism and the push rods. A tight adjustment will ensure disengagement but a continuous side load on the clutch could bring about overheating of the thrust and mainshaft bearings and that could lead to a blown gearbox.

The final drive chain and sprockets are sometimes a very neglected item and there's really no excuse for it. A lot of street riders don't like to oil the chain because it throws the oil on the



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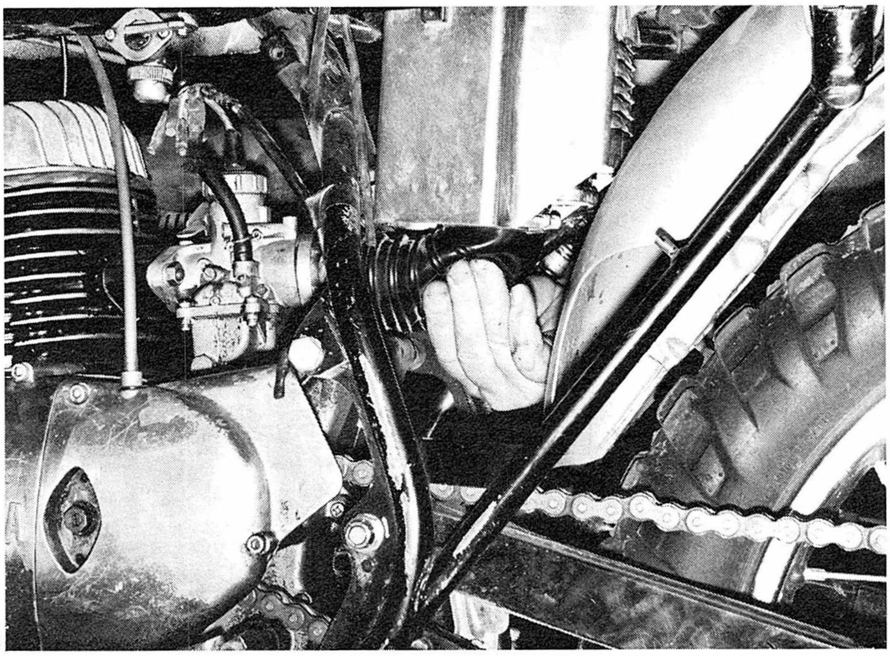
wheel, fender and up their back. Well if that's your problem, Bunky, you don't know how to oil a chain! A dry chain may be clean but it can sure cost you in sprockets, chain and maybe a busted engine. The foaming spray can chain oils are easy to apply and you won't get too much on if you go around just twice, once on the edges of the links on each side. Leave the bike up on the center stand and spin the wheel by hand and give the oil a chance to work in. Then wipe off any excess from the outside with a rag and you shouldn't have any problems. The rear chain should be oiled at least once a week and daily in wet weather; it should never be allowed to run dry or get rusty. The chapter on chains will give you more on adjustment and checking for wear.

WHEELS & BRAKES

Again, it can't be stressed too heavily: keep your spokes tight! Not too tight, and don't make like tuning a harp! The nipples should all be tightened to about the same torque; it was never intended that the spokes



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1. With no more than a couple of thousandths wear, new rings will seat right in to a well-honed barrel. Move the hone back and forth to get a coarse criss-cross pattern.

2. A filter should be like new on the inside no matter how bad the outside looks. Heavy grease around the edges will help prevent any sealing leaks.

3. Soft rubber air cleaner hoses should be checked for firmness. Continuous soaking in fuel tends to weaken them allowing collapsing under heavy load.

all strike the same note. The chapter on suspension gives you some tips on how to check for loose wheel bearings and this is fine for an occasional safety check, but at least once a year, and oftener if you're a mud rider, the wheel hubs should be checked to see that there is plenty of grease for the bearings and that the seals are keeping dirt and water out. Actually if this isn't the case you will have found out about it when you do the shake test on the bearings. If you have chronic troubles with bearing wear due to dirt and water the bearings can be replaced with industrial types that have an integral seal built in between the races and come all ready greased, permanently.

Brakes are of course subject to wear just as in any other vehicle so they will need some periodic attention. Most European bikes have riveted brake linings and just about when the adjustment in the cable or rod runs out, the linings are down to the rivet heads. It shouldn't have to be said, but don't try to run the brake lining beyond the rivets, it will only chew up the drums and they are almost impossible to turn out and very expensive to replace. Brake linings are not difficult to replace as can be seen in the illustrations and the cost of the parts is nominal. Complete replacement shoes are also available if you're not inclined to riveting. The Japanese bikes are all equipped with bonded linings but they really don't have any longer useful life than the riveted type. . . . the big advantage is that there are no rivets to ruin the drums. Don't be tempted to get the full wear out of the lining by relocating the brake lever on the cam splines; as the brakes wear further the cam has to rotate further and may have a tendency to get high centered between the shoes and lock up or be slow to release. This can be a very dangerous situation, and the low price for replacement shoes doesn't warrant the risk.

Brake adjustment is a matter of personal preference. Some like 'em tight and some like 'em loose. If you're one of the latter type, don't fall into the trap of letting them get too loose and then running out of full braking power in a tight situation. The hydraulic brakes found on the super bikes are a real boon to the biggies and the disc types are the simplest to maintain. It's hard to generalize about disc brakes because it seems they all have different arrangements of caliper mounting. Adjusting and servicing are covered in the owner's and service manuals. Don't let the friction pads wear too far as the disc rotors are as expensive to replace as hubs.

When reassembling the brakes don't forget to apply a small amount of 'Lubri-plate' to the cam and shoe pivots and to the ends of the shoe return springs, to keep them from rusting. Badly rusted springs should be replaced without question; if one lets go it's a locked-up brake for sure. An occasional drop of oil on the cam shaft between the lever and backing plate will find its way in to keep the brakes working smoothly.

SUSPENSION

The chapter in this book on suspension is very complete in both theory and practice on the care and feeding of shocks and springs. All you have to remember is to keep your eyes open for tell-tale clues on the condition of the parts. Fork seals aren't really leaking until the oil reaches the axle on a day's ride. A little oil around the scraper lip is really nothing to be concerned about. It helps to keep the fork tubes from rusting. An important thing is to keep the oil in the forks clean. Generally, hydraulic forks are pretty well sealed and dirt being sucked in with air is not the problem. Depending on the design of the fork, wear takes place due to the sliding action and the forks become filled with metallic particles that can accelerate the wear at a greater rate. What you're going to have to do is use your own judgment as to the rate of wear by changing the fork oil often when you first get a bike and seeing how long it takes to get the oil filthy.

Dirt is a problem where the seals are concerned. Off road bikes are the most vulnerable but street bikes aren't immune to the grit that gets on the fork legs and then works its way into the seals. For this reason the scrapers that keep the dirt pushed back from the seals should be kept in good condition and if the bike is equipped with accordion boots they must be in top shape also.

The rear shocks are usually so well sealed that leakage is rarely a problem. The thing to watch out for with these is the rubber bushings in the eyes at each end of the unit. The springs at both front and rear may be subject to losing some of their 'sap' so checking their length against new ones isn't a bad idea either. Most important is the security of all the mechanical and attaching parts in the suspension system. The steering head bearings, rear swing arm bushings, front fork yoke clamping bolts

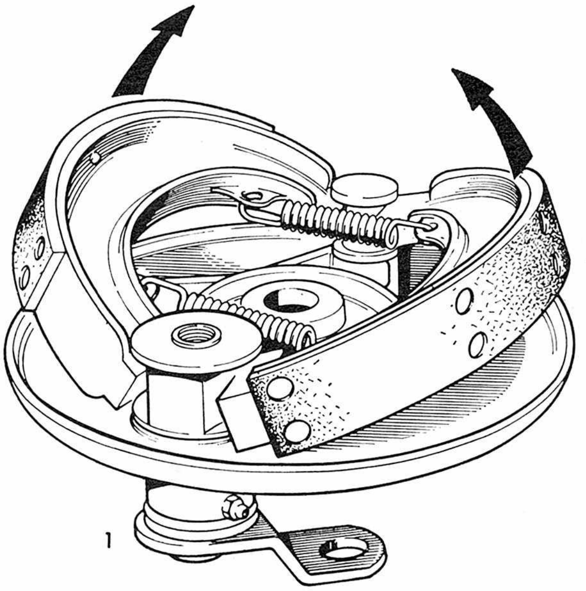
and the rear shock bolts should all be checked for condition and tightness at not too infrequent intervals.

FRAME

That maze of tubes, gussets and brackets called the frame or chassis is the thing that holds it all together but is seldom given much attention because it is thought of as not doing anything. Just because you don't see any moving parts on the frame doesn't mean that it isn't flexing its muscles. Everything in the frame structure is subject to bending and vibration as long as the engine is running or the bike is moving. Most of the time the deflections in the frame elements are very small such that they return to their normal state without apparent effect, but these deflections are of a continually repeated nature and the effects of fatigue will show themselves given sufficient time. The time it takes for this to happen will vary depending on the type of riding you do; the faster or rougher, the sooner things will happen. This is where the good thorough wash job and a long sit-down and look-see can pay off in stopping the damage before it goes too far.

The most critical points to look for frame damage are where the steering head is met by the main tubes, the engine mounting plates or brackets, the rear swing arm pivot mounts and gussets, and the junction of the top rear section with the forward section. Pull the tank, seat and side covers and squat down with a flashlight in hand and start gazing into those dark corners and recesses. It's really amazing what all those bits and pieces do; try to visualise what is happening as you bounce along and you'll get some idea of the punishment that things are taking. Look for cracks in areas right next to the welds; this is where the metal is most affected by the heat of the welding process and the stresses are greatest where loads are transmitted from one part to another.

The main frame isn't the only thing that gets a lot of gaff. The battery box, gas tank mounts, muffler brackets, air cleaner supports, oil tank hangers and every piece that holds another in place suffers the torment of engine vibration and may give up at any time causing further damage. There have been cases where things like the ignition coil or the horn bracket on some bikes crack off in just a few miles of



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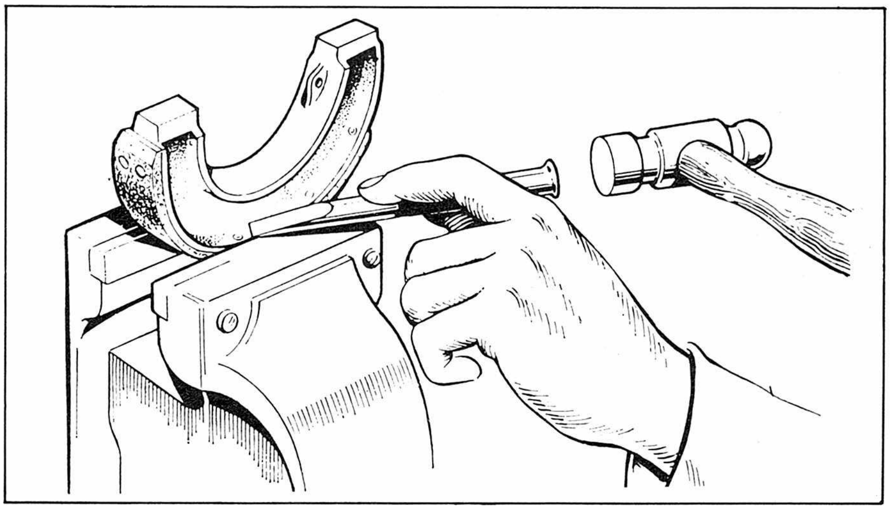

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high speed running at a constant speed. A good general rule to help speed the process of looking is that anywhere two parts are held together by welding, nuts and bolts, or any other means is where failure can occur.

Another important thing to look for that will eliminate a lot of rattles and noises are worn rubber bushings and grommets that are used in the mounting of many parts to protect them from vibration damage. Such attachments usually have a shoulder bolt or bushing to prevent over tightening of the cushion. Don't ever attempt to override these devices or overtighten unbushed cushions, and if any of them begin to crumble with age or wear, replace them with new ones. They are very inexpensive and if you don't think they do any good, try going without, you can shatter a gas tank, license plate or whatever in no time at all. See the chapter on 'Chassis' in this book to get a rundown of the various types and what they do.

CONTROLS

Ever give a quick pull on the clutch or twist the throttle and have nothing happen? Broken cables are something that should never happen to someone who spends a lot of time preparing for a big outing on the bike and expects to get his money's worth. Broken cables seem to be chronic with some people and others seem never to have the problem. Although they seem to be something that should naturally suffer a lot of wear because of the way they are made, cables will last indefinitely if properly installed and cared for. Cable routing is an art that has been mastered by very few, even the factories do a poor job in many cases and the cable replacement market prospers from it. You don't have to be a part of it though, just make sure those cabes are running the easiest way. The ends of the cable are where they seem to break most often and that is because they are routed such that there is a

strain on the cable as it approaches its anchor point.

As long as the cable makes a straight run from its end point so that the inner wire is not rubbing on the edge of the outer sheath or any of the hardware outside, it will not wear out. Cables are also limited in the tightness of bending they can stand so, the bigger the bend radius, the longer it will last and the easier it will operate. This is the test of a properly installed cable: under full load there should be no appreciable drag or binding because of the cable. Dirt and lubrication are other factors in cable operation that should be considered. Off-road bikes suffer the most from dirt and extra care should be taken to protect cable ends from its intrusion. Lubrication should be made an annual affair with routine of overnight dripping. Some of the newer cables have a nylon lining in the outer sheath and require very little oil.

Other types of controls don't require much attention but there are a few things to watch for. If your throttle has an unaccountable bind, make sure the entire assembly isn't pushed onto the bar such that the inside of the grip is rubbing against the end. The throttle should be removed occasionally for a good cleaning of the bar and inside of the grip body. Apply a very thin film of grease and re-install, and make sure that dirt isn't finding its way into the handlebar through chewed up ends of the grips. The rear brake pedal should be checked for wear in its pivot, and rod joints will wear pretty rapidly if the bike sees much mud. Make sure the rear brake rod isn't rubbing against some part of the frame or swing arm. Handlebar squeeze levers can contribute a lot of friction and an occasional tear-down and cleaning plus a drop of oil will make them feel like new.

ELECTRICAL/INSTRUMENTS

The chapter on electrical systems will give you a good run down on theory and trouble shooting, and your biggest problem is in keeping the wiring in good condition. Plain old wear is a big problem with wiring. Vibration, rubbing and chafing, and just flopping in the breeze can do more damage and cause more trouble than you can shake a stick at. The plastic insulation and harness sleeves used nowadays is real good stuff as far as weathering and resistance to oils and chemicals, but it still has to be tied down and tucked out of the way. The transition from the handlebar/front fork area to the main frame is where the wiring takes the worst beating. Make sure there are loops as large as possible in the harness so that when the bars are turned, the wires will not be kinked. Also see to it that the wiring isn't being pinched in the fork stops or between the tank and forks. Corrosion in the connectors can also be a problem, and poor grounding of the various accessories will make for erratic operation. Be on the lookout for loose connections too, check that battery regularly and it will have a long life.

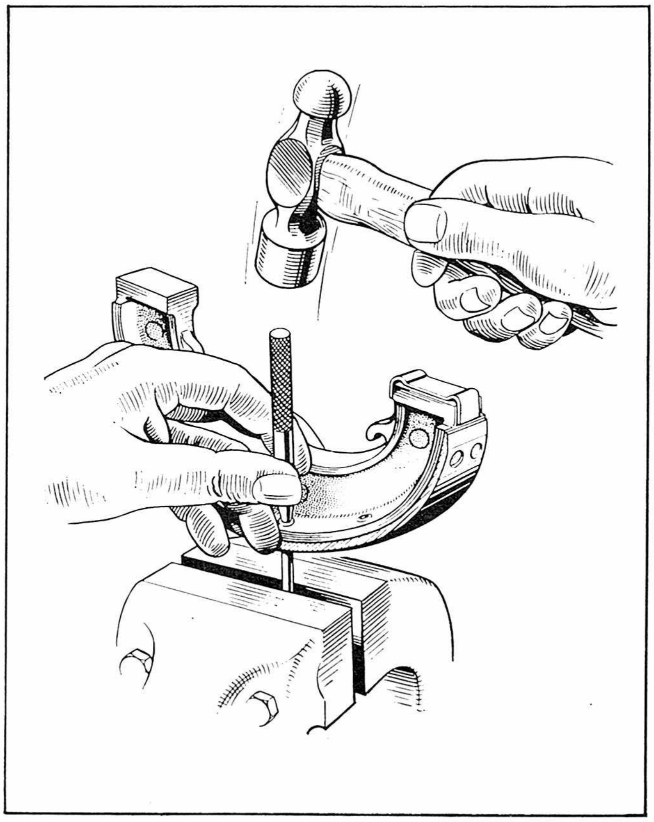
Speedometers and tachs will give very little trouble if they are mounted super soft to keep that real hard engine vibration out. The cables should be greased about once a year, and their routing should be given the same care and attention as control cables and wiring.

1. Tugging at the brake shoe springs really isn't necessary. Shoes may be removed very easily on most bikes as shown here. Clean thoroughly and lube before re-installing.

2. Rivetted brake linings are easy to replace with the proper tools. A sharp cold chisel and punches of various sizes are a good tool investment that will find wide use.

3. When rivetting on new linings, start in the middle and work toward the ends. This minimizes creep and hole mis-alignment. Brass rivets come with lining and are easy to drive.

4. Tachometer and speedometer cables should be cleaned and lubed annually. A light coat of high-temp grease will not 'migrate' to the bottom. Too much grease can foul the instruments.



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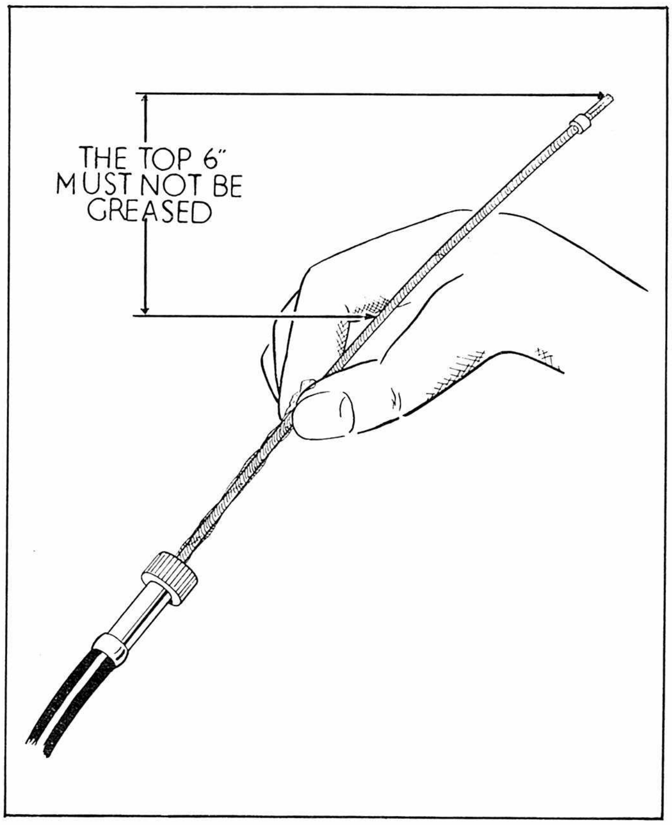

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WELDING, BRAZING, SOLDERING AND RIVETING

It's only after you learn these metal joining techniques and put them to use that you realize how limited you were without them

BY DALE BOLLER

It is virtually impossible to be a good do-it-yourselfer without having the ability to join metals together by permanent and reliable methods. Welding is essential in everything from creating your own frame to mending a cracked fender, while solder is the backbone in joining your machine's wiring network; a few rivets here and there can eliminate vibration prone nuts and bolts and make "old reliable" more likely to stick together through the toughest treatment you can dish out.

An oxyacetylene torch set or an electric welder will cost over $100.00. While welding equipment can be rented or borrowed, the serious enthusiast should make the purchase of such equipment an immediate goal. As an inducement, the beginner can expect to pay for a welding set with welding jobs from his friends—providing he has taken the time to learn welding properly and his friends don't expect to have it done for free. It will be possible to learn welding theory from the information contained within this chapter, but the beginner is advised to seek experienced assistance where feasible.

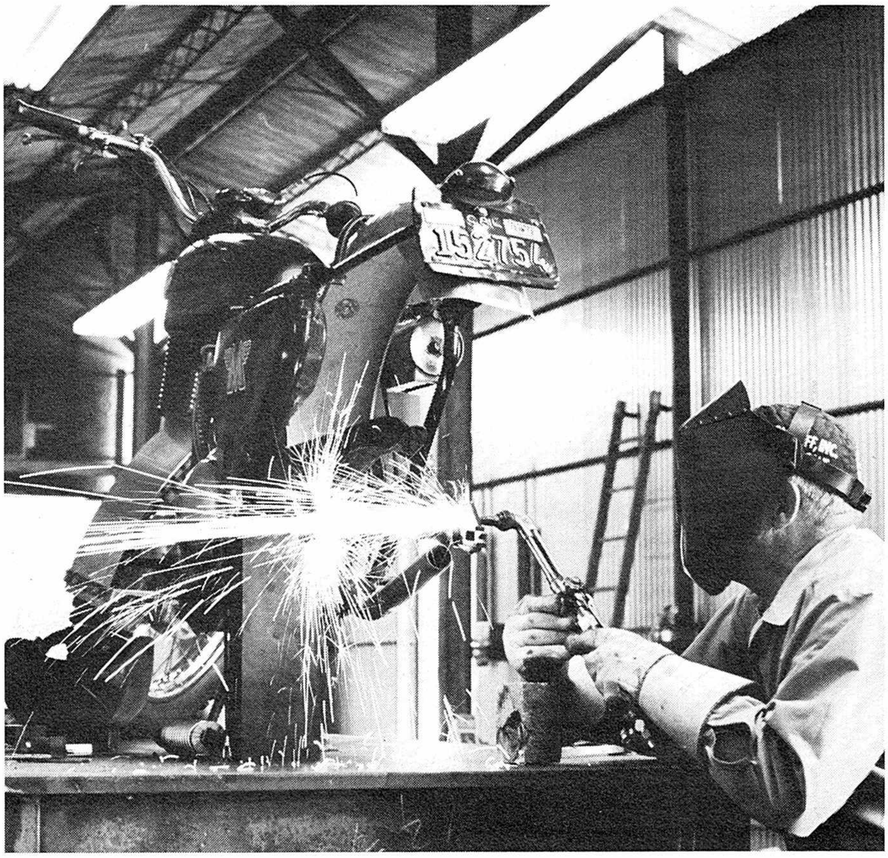
PLACES TO LEARN WELDING SKILLS

Most high schools offer an expanded auto and farm shop program that includes welding. These programs are ideally suited to students, but adults must often take advantage of night courses. Most welding companies sponsor welding seminars in selected centers, with classes that range from a few hours during the evening to several days. Gas welding company representatives often hold special short seminars at garages, and local auto parts houses know when these demonstrations are to be given. Electric welding companies such as Lincoln have special three-day courses usually taught at colleges during the summer. These are normally aimed at farmers, but the basics of good arc welding are the same everywhere. For information on an arc welding course such as this, check with a local school shop instructor, or write to a manufacturer.

Finally, most blacksmith shops have excellent welding services, with personnel who will be willing to share knowledge on welding. Other places to look for excellent welders include oil field crews, body shops, heavy equipment maintenance shops; and county or state road department shops. It is possible to learn exotic welding from specialized shops, such as the heavy equipment garage or airport.

The different types of welding can be classified readily by the method of joining. Metal can be heated to the melting point so it will flow together and form a bond; metal can be heated to near melting point and then joined by force; or metal can be heated and joined by diffusion or a secondary filler material. Fusion welding—where the molten parent metal flows together—includes both gas and electric processes. Pressure welding is the name given to forced fusion, such as electrical resistance (spot welding) and the old-time blacksmith forge methods. The last technique includes brazing and soldering, with soldering restricted to very low temperatures and brazing somewhere between fusion welding and soldering. While fusion is considered the stronger, the introduction of new high-strength brass combinations offers some outstanding possibilities for this lower-temperature joining.

Because of the versatility, a gas welding outfit is the best initial purchase. Such equipment consists of an oxygen cylinder, acetylene cylinder, oxygen and acetylene regulators, hoses, the torch (mixing chamber, tip and handle), goggles, spark lighter and usually a wheel cart.



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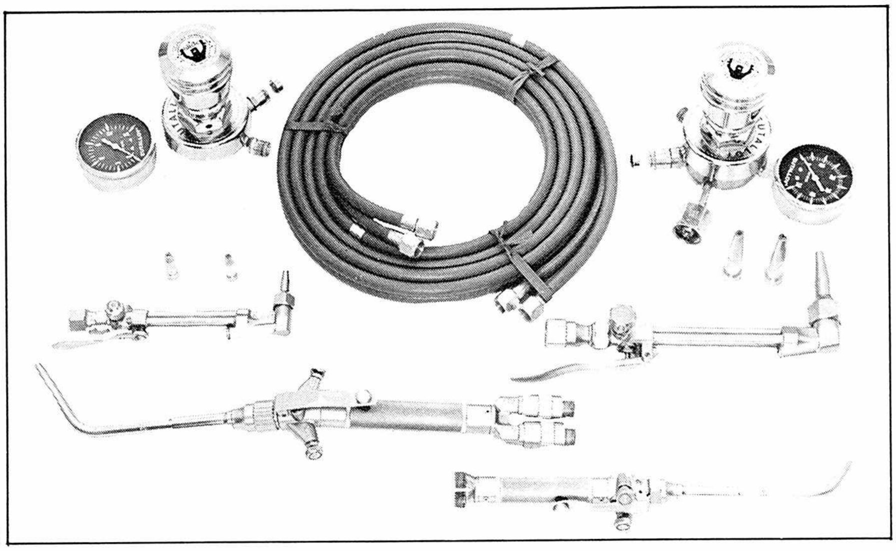

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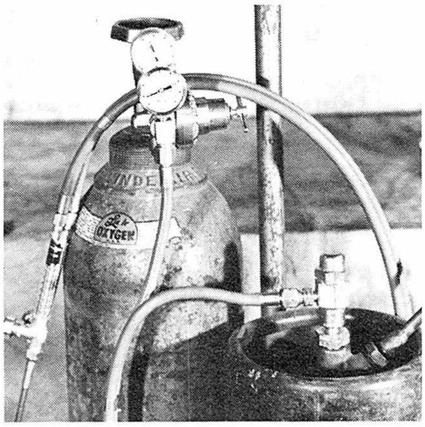

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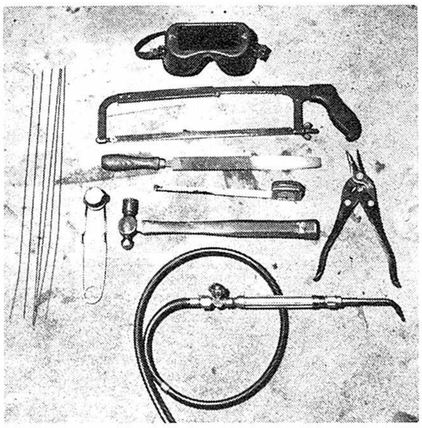


1. A variety of equipment is available for gas welding; these mixers, cutting attachments and tips are typical. A single dial gauge is adequate for the home craftsman. The complete kit comes from Eutectic Manufacturing Co.

2. Gas bottles are usually leased from supply companies; everything else belongs to user. Universal tool will adapt to all attachments in outfit.

3. Other and sundry items used are goggles (a must), saws, files, a hammer, tape measure and sheet metal clippers. It's best to keep these with welder.

It is not common for the gas cylinders to be purchased. Instead, the welding equipment company normally owns the cylinders, leasing them out for certain periods of time at standard rates. These rates will vary with the size of the cylinders, but for the medium-size bottles the cost is around $80.00 for 20 years. Numbers on the cylinders are carefully recorded, and every time the cylinders are filled the numbers are checked against a master theft list. There are some privately owned bottles, but they are rare.

When considering what welding gas company to do business with, concern should be directed, of course, to the initial cylinder leasing cost. At the same time, find out whether or not the company will deliver full bottles. Often a welding equipment outlet will supply cylinders on a demurrage-time plan where the user agrees to buy so much gas per month. This normally means a full set of bottles every month, with medium-size bottles costing about $12.00 a pair to fill. Obviously it is cheaper to lease long-term bottles.

As to the size of cylinders to use, this will depend a great deal upon the amount of welding anticipated. Small bottles are very handy, particularly if they must be transported, but they do not hold much gas (50 cu. ft. oxygen, 40 cu. ft. acetylene). The large-size shop bottles are really too large for the home craftsman (275 cu. ft. oxygen and 340 cu. ft. acetylene). The medium-size bottles are just about right (125 cu. ft. oxygen and 120 cu. ft. acetylene), although some kind of cart is definitely recommended. Safety is vital when using these gas cylinders, and they must be secured so they can't be knocked over.

Oxygen bottles are very high-strength cylinders because of the very high pressures involved. A standard-size bottle may have as much as 2200 psi at 70° F., a pressure that will increase as the temperature goes up. The bottle is topped by a bronze shut-off valve with a safety device to release pressure under emergency conditions. A gauge on the valve is calibrated to indicate bottle pressure at 70° F. These bottles should never be stored near high-heat sources or flammable materials such as paint.

Also keep in mind that oil and grease do not combine safely with oxygen (the cause of some long-unexplained aircraft accidents). Just a drop of oil in an oxygen valve can cause fire and/or explosion, and you can expect the same kind of results with greasy rags or clothing.

ACETYLENE STORAGE

The acetylene cylinder is different from the oxygen bottle because acetylene is dangerous to store at high pressure in open-space containers. For this reason the acetylene bottle is larger in diameter and filled with something besides the gas. That is, acetylene compressed at high pressure will tend to break down into its more basic elements if subjected to hear or shock, leading to a tremendous heat release.

Acetylene can be easily dissolved into acetone, however, at many times the volume of the acetone, and the cylinder can be filled with a porous material such as balsa wood which will accept the acetone and reduce problems of shock. There are safety fuse-plugs at each end of an acetylene cylinder. These plugs are designed to melt at 220° F., allowing the acetylene to escape and thus avoiding an explosion. Because of the acetone, an acetylene cylinder should never be stored or used in a horizontal position, and should always be allowed to stand for a while before use if it has been lying down. Otherwise some of the acetone can be forced through the hoses and torch, causing a void in the cylinder, which may prove to be dangerous. Obviously welding bottles are not to be played with, but if treated with common sense they are very safe.

Incidentally, acetylene is much more subject to recorded pressure changes relative to outside temperature. For this reason the amount actually in the bottle and what the bottle gauge reads may vary considerably. There is an empty bottle weight

stamped on the bottle, however. To determine how much acetylene is actually in the cylinder, weigh the cylinder, then subtract the stamped empty-bottle weight. Acetylene gas weighs exactly one pound per 14.47 cu. ft. of gas.

The parts of any gas welding equipment that are commercially available are usually considered as a unit and consist of the hoses, gauges, torch, goggles and striker (spark lighter). These welding kits are available from a wide number of manufacturers. There is a difference in the type of kit, however. Most of the kits sold for the home craftsman feature the smaller gauges and torch. There is nothing wrong with this, since the average enthusiast will seldom work on any really heavy metal. In fact, the smaller torch is easier to use because of its lesser bulk and lighter weight.

REGULATORS

The regulator for both oxygen and acetylene operate the same way, but they are not interchangeable. For safety reasons, the acetylene connections at both regulator-to-tank and regulator-to-hose have a left-hand thread. A left-hand thread is also used at the torch mixer so there will be no possibility of getting the regulators or lines swapped. Regulators will seldom give any trouble and can be returned for repair if found defective.

Gas welding hose is made specifically for the job at hand and no other kind of hose should be substituted. It is flexible, non-porous, and strong enough to take the high-pressure gases. The hoses are usually connected as a single unit to make them easier to handle, with the acetylene hose colored red and the oxygen colored green or black. The threaded connections are grooved on the acetylene and can be replaced if they are damaged or wear out. Such hose is not expensive, so it is advisable to obtain enough to service the average home shop, which is at least 15 feet.

The torch does all the work of mixing the oxygen and acetylene in just the right amounts. To do this, the torch body employs control valves and passages for the gases, plus a mixing head. Interchangeable tips are used with most torch bodies, tips that come in a variety of sizes depending on the work required. The control valves for most light-duty torches are at the front of the handle; for heavy-duty torches they are at the rear.

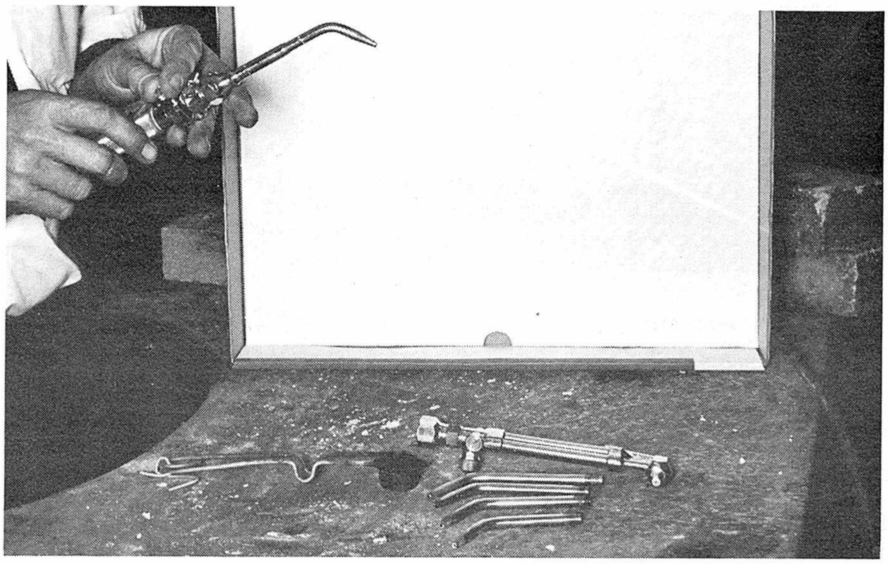
Interchangeable tips are made to cover a wide range of uses, although the enthusiast can usually do with just three. The smallest tip in the line is normally for light work, such as welding fenders. A mid-range tip should be selected for heavier work, such as frame tubes and thin-steel plate. A large tip suitable for heating thick steel plate should also be on hand. With these three units most any job can be accomplished satisfactorily.

A torch is not a pry or a hammer, something the non-professional usually learns by experience. The tips can be easily bent and flattened, and the adjusting valves can be bent and broken. As a good habit to develop, always hang the torch up as soon as it's no longer needed. This can be close at hand, but it keeps the unit off the floor and out from underfoot.

Any time a new tip is being installed, go easy. The mating surfaces of the mixing head and the handle can be scratched and/or nicked. A bad practice is to overtighten the tip, mixing head or valves by using too large a wrench or too much pressure. The valve seats are especially susceptible to this kind of damage. It is also possible to overtighten the sleeve nut holding the mixing chamber. Finger-tight plus a little more is enough. If the torch will not stay "set" once the gas proportions have been reached, chances are the valve nuts (the ones holding the valve to the torch body) are slightly loose. If they are too tight, the valves are hard to turn.

WELDING STEPS

When setting up a new welding outfit, the following steps should



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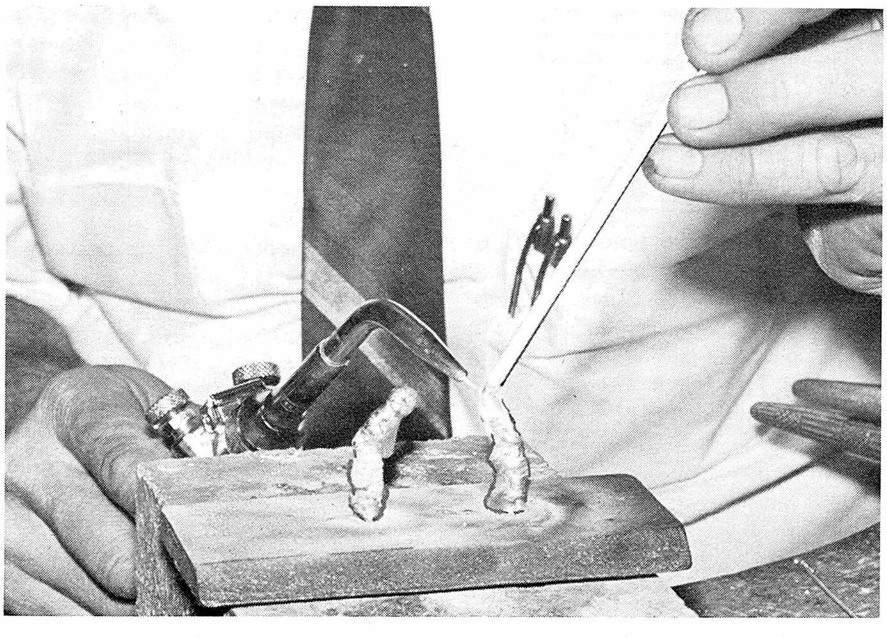

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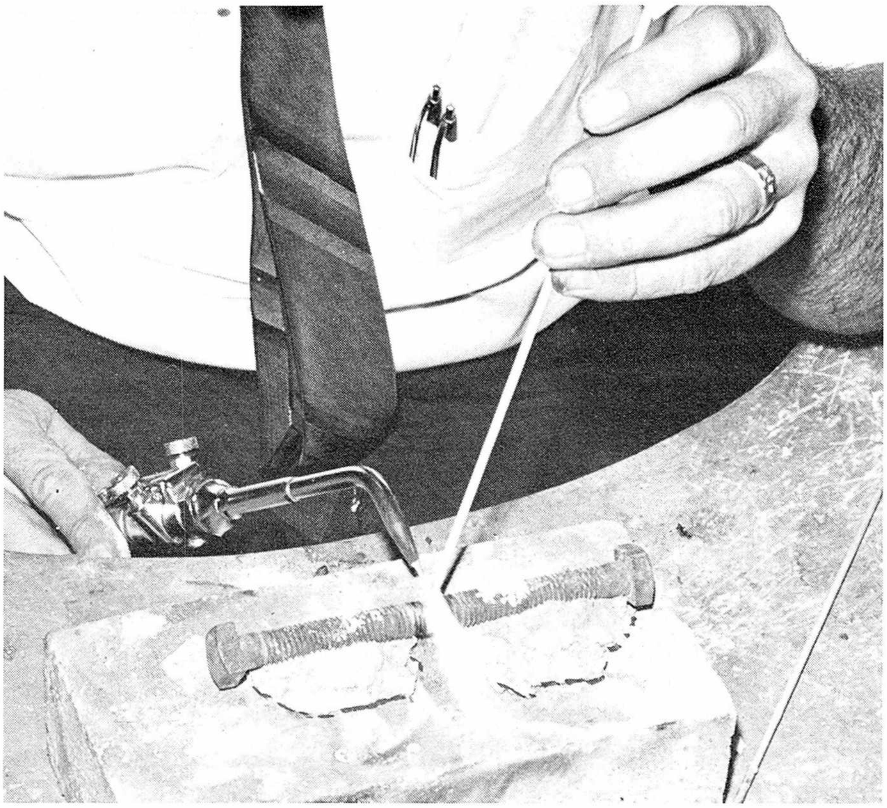
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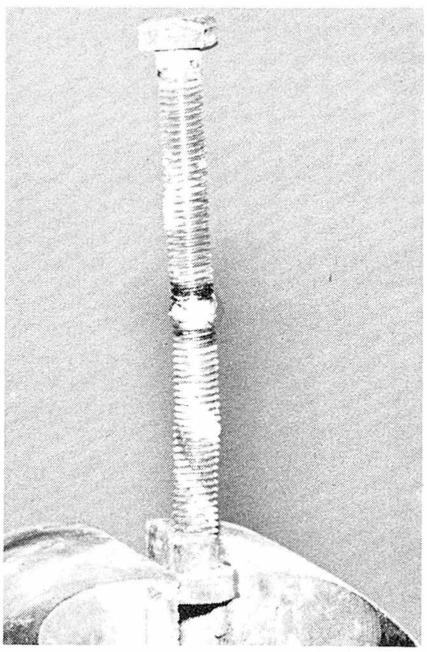
1. The acetylene/oxygen mixture and type of tip will determine the flame's characteristics. Long whitish cone is preferable for carburizing.

2. Stacking quality of brazing rod is evident here. This is a good practice exercise for beginning welders.

3, 4. In a graphic demonstration of the strength in welds, two bolts are joined end to end. Note how torch and rod form a visual "V." The joined bolts were indexed with a straight-line chalk mark, then twisted two full turns with the weld remaining intact. Another half-turn and the bolt broke ½-inch from the head. This indicates no strength loss near weld from heat.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serve as a good guide. They should also be followed if the equipment has not been used for some time.

1) Secure the gas cylinders in an upright position. If no cart is used, chain them to a post or to the wall.

2) Check the inlets of both regulators for foreign material and clean them. Also check the outlets of both cylinder valves.

3) Dirt can be blown from the cylinder valves by opening the valves very briefly. Do not leave them open for any length of time.

4) Connect the regulators but do not overtighten the male or female connections. The hoses are not connected yet.

5) Release the adjusting screws on the regulators, then open the cylinder valves. Note the pressure obtained, then close the cylinder valves.

6) Watch the pressure gauges for any drop in the reading. After several minutes the pressure should be the same; if not, check for a leaking connection, creeping regulator valve, or regulator leak. If the problem is more than a leaking connection, the regulator should be returned for service.

7) The regulator should be blown out by turning in the adjusting screw just enough to release a small amount of gas, then shut it off.

8) The hoses are attached to the regulators but the torch is left off, then the hoses are blown clear.

9) The torch handle is attached minus the mixing head and blown out by opening each valve separately. Adjust the regulators to maximum working pressures (which is 15 psi for acetylene and 14 to 30 psi for oxygen), then close torch and cylinder valves. Check the gauge's reading and then check again after several minutes. If the pressure drops, retighten the connections. If the pressure still drops, inspect the hose for breaks.

10) Attach and blow out the torch mixing head by turning the torch oxygen valve wide open; check both gases for smooth flow.

11) Attach the tip and then light the torch.

While such an initial precaution is not likely to show anything wrong with a brand-new piece of equipment, used equipment will often show problems. If there is any dirt between the regulators and the torch mixing head, chances are the dirt will be lodged in the head, making it difficult to obtain a good torch setting.

Every time the bottles are changed, care must be taken not to damage the regulators. Also check for foreign material on both the gauges and the cylinder valves with each change, paying particular attention for fire-producing grease and oil.

LIGHTING TORCH

For the beginning welder, lighting the torch and setting up the proper flame for the job seems to give the most trouble. After the cylinder valves have been turned on, turn the regulator adjusting screws in until the desired hose pressure is reached. These pressures will be modified by the tip size, although anything under a #5 tip will normally have five psi. A slightly high pressure will not be a problem, but it will make the flame adjustment hair-trigger sensitive.

Next open the acetylene valve on the torch approximately ¼ turn and strike a flame with the spark lighter. The acetylene will burn with a long, yellow flame emitting heavy soot. It is possible to reduce this sooting by also opening the oxygen valve very slightly before lighting, but this is something that comes with handling experience.

Open the acetylene valve until the yellow flame is rushing from the torch

WELDING

and just barely begins to pull away from the tip, then back off on the valve until the flame touches the tip again. Open the oxygen valve and note that the flame begins to include several cones of blue flame, all of different shades. As the oxygen valve is opened further the flame cones will seem to recede back into the torch tip until finally only one very sharply defined dark blue cone remains.

The size of the tip should always be varied to correspond to the job being done, even though some slight variation in flame can be produced by increasing or decreasing the quantity of gas flowing through the torch. If a large tip is used and the gas adjusted to a very low flow, it is possible to backfire into the torch. This uncomfortable situation is accompanied by a very noticeable buzzing sound from the torch. The course of action is to immediately turn off the acetylene at the cylinder valve, followed by the oxygen. If not, the flame can continue retreating up the assembly.

Another problem that concerns the beginner is the momentary loss of flame when welding. This is usually caused by a hot particle popping into the tip opening, temporarily cutting off the flow of gas. The particle immediately cools, however, and is ejected. The gas then re-ignites. All this happens rapidly, and sounds like a sharp rifle shot. Sometimes, it will be repeated in rapid succession. If such a situation persists, go to a larger tip which will generally clear up the problem. Learning to adjust the flame until the welding operation goes smoothly is 90 percent of the battle and cannot be overemphasized, as too much or too little oxygen will be readily apparent and the welding will not be smooth.

ANATOMY OF FLAME

A gas flame, in reality, is two flames: the very hot inside cone, which rises up to just over 5800° F. (it can be made hotter by adding oxygen, but then it is not suitable for welding), and the outer sheath flame. It is the short inner cone that is used for welding. By adjusting the acetylene and/or oxygen valves, the flame produced can be changed from neutral, to carburizing, to oxidizing.

The neutral flame throws off neither carbon from the acetylene nor excess oxygen to contaminate the molten metal. The gases mix and burn with complete combustion, the reason for the sharply defined inner cone. When welding with a neutral flame, the molten metal's puddle will appear clean and flow easily.

The carburizing flame will show up as feathery streamers off the inner cone and can be present even if the valves seem to be set perfectly. Such a flame will make the molten metal boil and lose the clear appearance from a neutral flame, which is caused by the addition of carbon from the flame. The problem with this flame is that it leaves a brittle weld and will make the metal too hard during shrinking.

There is no use for the oxidizing flame in welding. Too much oxygen shows up as a smaller than normal inner cone and a hissing noise from the torch. When the flame is directed at the molten metal puddle, it causes the metal to foam and spark, creating the illusion of a granular formation. Such a flame could prove beneficial only as a poor substitute for the cutting torch. The area is heated as if to weld with a neutral flame, then excess oxygen is bled in to blow the heated metal away. This is sloppy practice and not recommended for beginning welders.

Now down to the nitty-gritty of welding. Making a good weld requires coordination of two things; the correct flame and the correct filler rod

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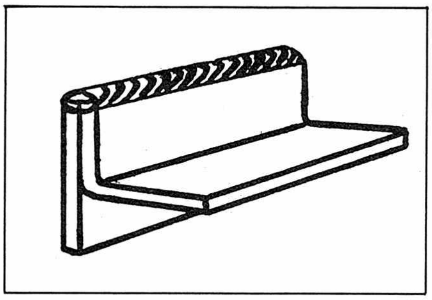

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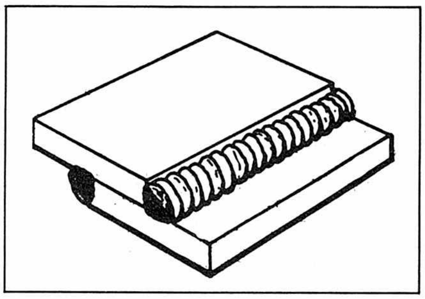

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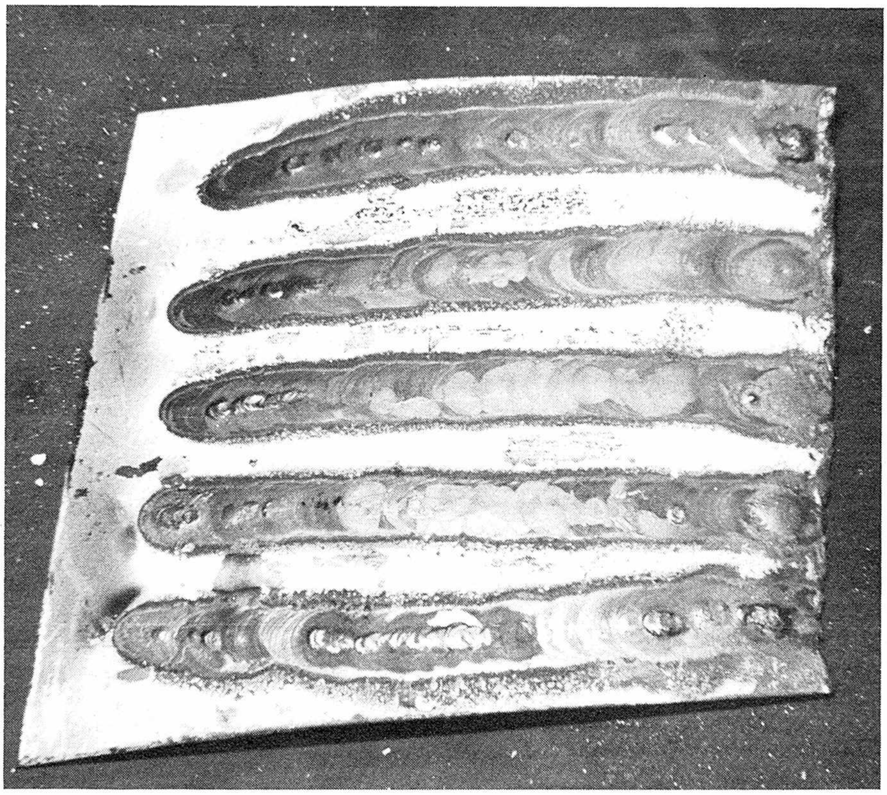


1. In joining two edges, less heat is required than in a lap or butt weld.

2. This type of lap weld is tricky because the solid piece does not heat as quickly as the exposed edge. Slower rod movement is necessary to spread heat.

3. The beginner will need a lot of practice before skilled sheet metal welding is mastered. Moving the torch at different speeds controls finish.

4. Flame temperature (controlled by the gas pressures and type of tip), dictates the depth of penetration and amount of rod to be used. Too much heat and too little rod warps sheet.

5. Just as important as welding itself is the ability to cut. Practice will perfect ability to make smooth cuts.

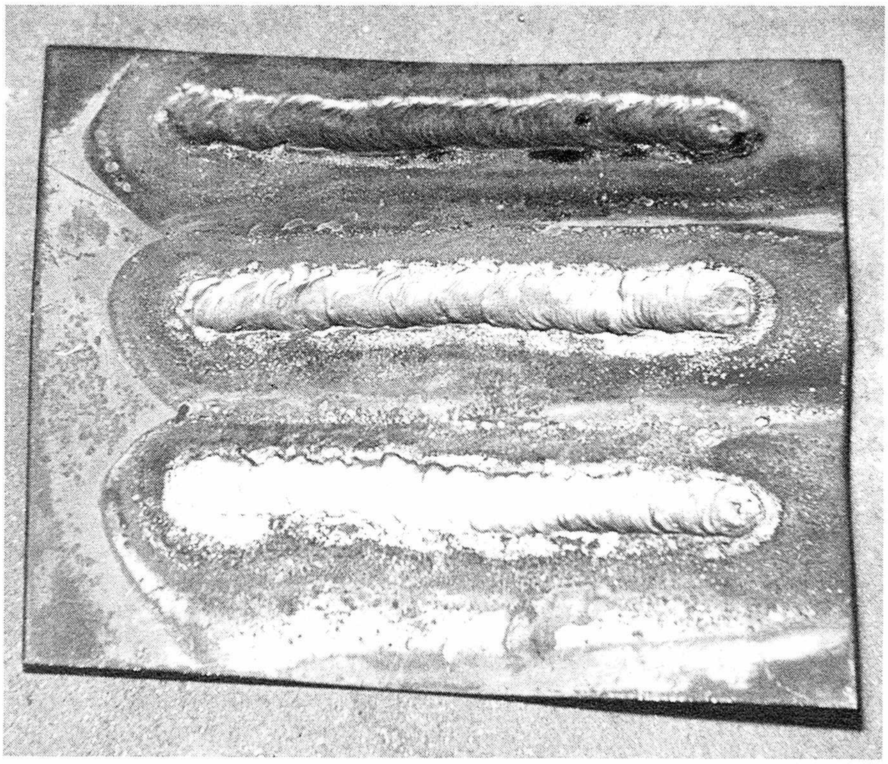
(if a rod is used). Most beginners make the mistake of moving the filler rod and letting the flame follow along. Just the reverse is required. To make a good weld, you must keep the proper distance from the flame tip (inner cone, remember) to the metal; the angle of the flame to the line of the seam must be right; the rate of travel is important, torch motion sideways must be controlled; and finally the filler rod end-position must be right in relation to the flame. All these things seem to go wrong at first, but with even 10 minutes' practice, the average enthusiast can begin to lay a good bead.

Perhaps the most important part of welding is learning to keep the neutral flame the correct distance from the weld. The distance of the flame from the work can vary according to the type of weld being made and the material being welded, but for general-purpose the inner cone should be kept approximately twice its own length from the surface. Temperature and spread of the heat involved are the keys; the inner cone temperature is nearly 6000° F. but the end of the large sheath flame is just over 2000° F.

CHOOSING TIPS

If a small tip is used, common to sheet metal, the above difference in temperature can occur in just a couple of inches.

A good welder wants to weld as quickly as possible and keep the heat as concentrated as possible, because major metal distortion can be caused by too much heat over a large area.



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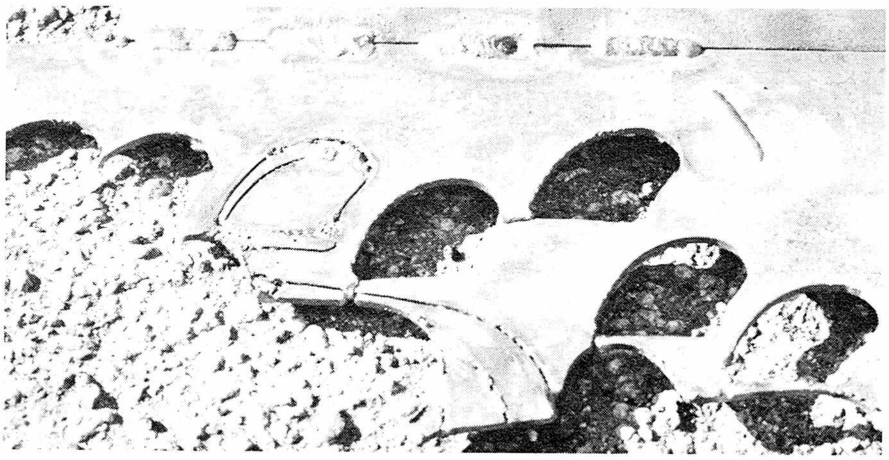

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If the metal is relatively thin, as in lightweight frame tubes, the tip can be small and the flame should be rather close to the puddle. This will give both good penetration and a strong weld. If the metal is thicker, a larger tip must be used and the weld may need to be made slower to obtain total penetration. If a light gauge is being welded to a heavier gauge, a larger tip for the heavier metal may be required and the flame directed primarily on the edge of the heavy metal. This brings up the importance of the angle of the flame to the work.

Flame angle will be different for different types of jobs, and will include the angle of the flame to the surface and the angle of the flame to the line of the seam (as above with two different-gauge metals). When making a simple butt weld on flat stock such as in a gusset or peg reinforcement the angle of the flame to the surface and puddle should be somewhere between 30 and 45 degrees, with flame pointed in the direction of travel directly down the seam. This will preheat the metal as the weld is made. If more heat, and consequently more penetration is needed, the angle is decreased. For less heat the angle is increased. For a butt weld the flame should be directed down the seam to preheat both sides evenly (for a butt weld the pieces should be tack welded before final welding) to have equal expansion. If the flame is pointed more to one side, that side will expand unevenly.

When making a lap weld, where one piece of metal is lapped over the other, flame control is even more critical. The top, or exposed, edge of metal will tend to heat and melt faster than the lower metal, so the flame cannot be pointed directly down the seam. Instead, the flame is pointed slightly away from the exposed edge, and the filler rod may be held to shield the exposed edge. Only experience will show exactly what is needed in both of these common welds.

How fast the weld bead is made will determine both the weld penetration and the width of the bead. The key to speed depends upon the size of the tip and flame, the thickness of the metal, and how big a bead is desired. Normally, the bead should be about ⅛-inch wide for sheet metal (wider for larger material) and be just slightly crowned from the surrounding metal. If the bead is lower than the parent surface, speed is too great; if it is higher, speed is too slow. If the bead

is too narrow, speed is too fast; and if it is too wide, speed is too slow.

With the torch held at the correct angle and distance, the rate of travel can be determined by watching the puddle. Note that the appearance of the weld puddle is also used in arc welding. The puddle is nothing more than a hot bead. At first the novice will tend to be either too fast or too slow, usually alternating between the two. When he sees the puddle start to grow too wide, he'll jerk the flame away from the bead and cause an erratic weld. If the bead is growing too large, merely speed up the rate of travel. Slight variations in the bead are not as important as its overall consistency.

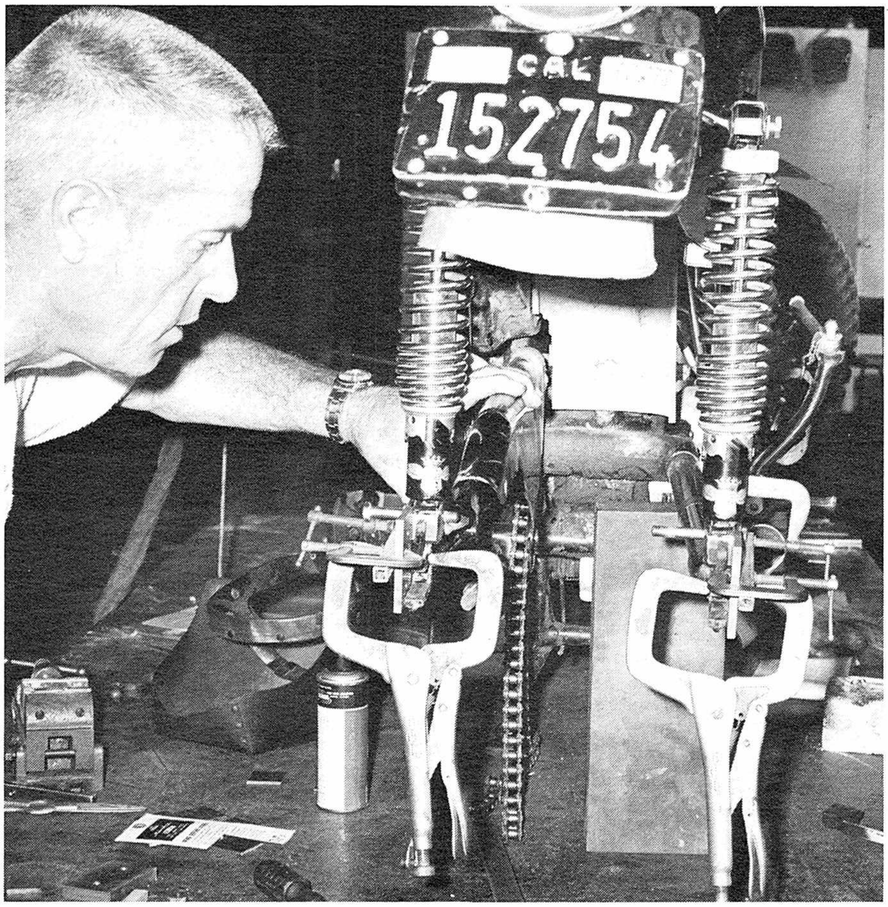
CONTROL OF FLAME

Control of the flame is vital to all kinds of welding, whether it be gas or electric. In a gas weld, there are two things to consider physically: control of the flame and control of the filler rod. In brazing this is not so critical because of the lower temperatures involved, but in fusion welding, the flame must be directed in a precise pattern to keep the parent metal at the correct temperature and at the same time melt the filler rod.

Learning how to weave the flame will help considerably. If the flame were pointed directly down the seam at the right angle and the filler rod were supplied at the right rate and angle, the flame would not have to be weaved. This kind of control comes only with diligent practice, and is applicable only to sheet metal.

If the flame is moved back and forth slightly at the same time the weld progresses down the seam, a kind of zig-zag weaving pattern is formed. This pattern will show in the cooled bead. Easier to master is the circular weave. The flame is rotated in a tiny circle as the filler rod is being fed. This pattern tends to keep the bead moving smoothly by melting the filler rod in drops during each circle by completely heating the parent metal and puddle. Of course, a weave will slow down the rate of travel slightly and will cause more distortion than the simple straight feed patterns. However, a weave is necessary with heavier metal.

The real problem with gas welding comes in trying to make the filler rod work in conjunction with the flame. It is something like playing the piano,



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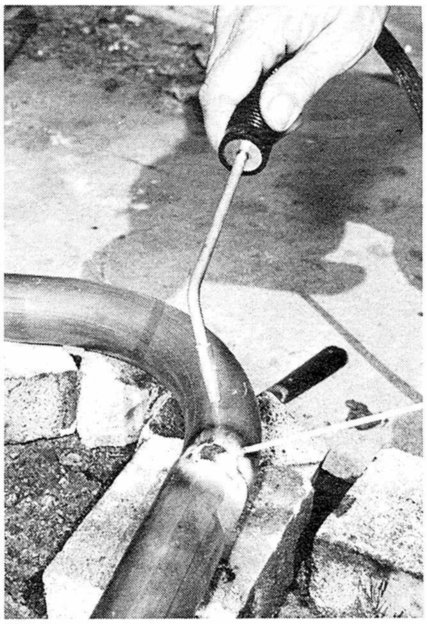

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1. Welding chassis and frame components is final test. Critical factor is to keep from warping any of the chassis components. Use vise grips and "C" clamps to hold everything in original location before lighting the torch. Remove gas tank and lines, too.

2. Special brazing torches are compact and handy for light duty work. Old bricks make good heat insulators.

3. Differences in flame temperature and skill of welder show up in passable weld (compared to a beauty). Example on left needed slightly higher flame temperature and smoother rod feeding.

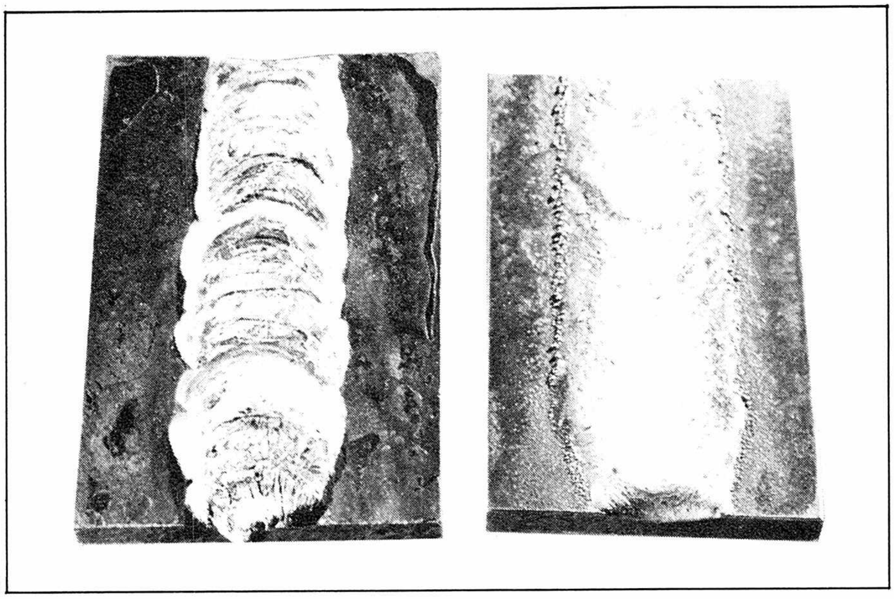
4. This torch kit is inexpensive, comes with solder point, but has no cord to ease workability for welder.

where both hands must work differently while concentrating on the same subject.

With a simple butt weld, the rod is held in line with the seam and tilted away from the torch at approximately 45 degrees to the working surface. The tip of the rod is kept inside the flame and slightly above the spot being heated by the inner flame cone. As the tip of the rod melts it can be dabbed into the puddle with the rod raised ever so slightly to melt another drop. This means a continuing up and down dabbing of the rod as the weld progresses. Of course, the flame can be moved in concert with the rod, which is what happens when experience is gained.

It is possible to keep the rod fed into the puddle as the bead progresses, and this is usually the case with a lap weld where the rod is shielding the exposed metal edge. Normally the student welder will find this is more difficult to master than the dabbing technique.

There are several problems to contend with when making an ordinary butt weld. In the first place, the pieces



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must be aligned. This means the surfaces should be flush (up and down) and spaced apart very slightly. A butt weld can be successful if the pieces are tight, but a slight separation makes welding easier. However, the space should never exceed the width of the filler rod being used, and in the case of sheet metal, a very small rod is used. For metal 1/16-inch thick or thicker, the space separation should be equal to the metal thickness.

TACK WELDING

When any seam is more than one inch long, it should be tack welded, otherwise the preheating effect of the flame will cause the metal edges to crawl together or separate farther and force the edges out of alignment. Making a tack weld is essentially the same as a full-seam weld, except that the torch angle should be less to concentrate the heat on a smaller spot. The entire idea of tack welding is to cut down on heat distortion.

After the initial tack is made, which is best placed near the center of the seam to be welded, the succeeding tacks should be spaced about three inches apart. As each following tack is made, the torch is pointed back toward the preceding tack to reduce distortion. When the edge is reached, the tip must be pointed off the edge for the same reason mentioned above. The tack should be as small as possible. If it's too large, the distortion factor becomes greater and may even be sufficient to require hammer and dolly work.

A lap weld also requires tack welding, but it is more difficult to do, both from the tacking and the final welding standpoint. When one piece of metal is lapped over another, there is nothing to keep the edges from crawling as in butt welding. This crawling can take place even while the tack weld puddle is cooling, and will proceed with each additional tack.

As with welding the seam, the tack weld must be done with the flame pointed slightly away from the exposed edge, and the filler rod, acting as a shield, must be next to the metal's edge. Making a small, fast tack is imperative. For the final weld, the flame is pointed more in line with the seam to keep the puddle moving down it.

The outside corner weld is the easiest of all gas welds because the flame tends to play the two metal surfaces, with only the edges being exposed to high heat. Tacking is necessary on long outside welds, but short welds of around three inches require no tacks. If the two pieces of metal are propped together evenly, the use of a filler rod may not be necessary. The flame must be pointed directly down the seam to obtain even preheating, otherwise one edge will distort unevenly and cause misalignment.

The inside corner weld is very difficult for the beginner because the heat is concentrated on the metal and distortion is great. These welds should not be attempted until the others are mastered, and both filler rod and flame can be well controlled. Usually such a weld will have a horizontal and a vertical surface. If so, the flame is directed more toward the vertical piece, and the filler rod is held over the flame instead of in front of it. A smaller tip will usually do a better job, as it will concentrate the heat deep in the corner and the flame tip can be held closer to the puddle. However, care must be exercised, as more flame is directed toward it, in order to keep it from undercutting the vertical piece.

There is a particular gas weld that is very similar to an electric spot weld, called the buttonhole. Here, two pieces of metal are lapped as with a typical lap weld. However, a hole is melted in the upper piece and then filled with filler rod that melts into both the upper and lower panels. The problem is keeping as small a hole as possible in the top panel. A small flame is necessary and the tip is held almost vertical to the panel. The rod is kept practically in the puddle and can be shifted around the hole circumference to shield an edge.

4

BRAZING

Learning to braze is easier, but the beginner is cautioned to learn fusion welding first, before attempting brazing. There are actually some professional metal men who cannot do fusion welding, mostly because they have never really tried, and this proves a definite handicap. For the do-it-yourselfer, fusion welding is an essential part of every project.

There is a difference between braze welding and brazing, although both use nonferrous filler rod that will melt above 800° F. In braze welding the filler rod of brass or bronze fills an open-groove joint or makes a definite bead. In brazing, a closely fitted joint is filled by capillary action of the filler material (as in furnace brazing). Such

a connection is really just a thin film of filler metal between the two surfaces, but it can be extremely strong. Furnace brazing is necessary when outstanding strength of precision parts is required.

Brazing is possible because many nonferrous metals will diffuse and/or penetrate into other metals when temperature and surface conditions are right. This means the copper base filler material must be melted but not heated above its melting point, while the parent metal must also be kept at the same temperature.

The parent metal must be clean, which can be accomplished by grinding, scraping or using a wire brush. An easier way—chemically—is to use a strong flux, but such a flux leaves a residue that is difficult to remove. You can use a combination of the two, cleaning the joint to be brazed and then using a flux with a low chemical residue.

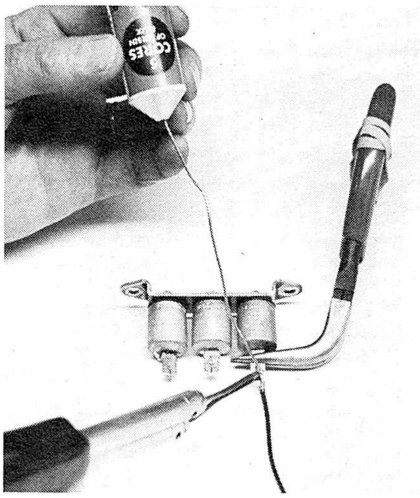
On a good brazed joint, the penetration is called diffusion since the two metals intermix to cause an alloying action at the joint's interface. Such an alloy is sometimes stronger than the parent metal, especially with the newer high-strength brazing rods. The strongest brazed joints are made when the parent metal surfaces are between .003- and .005-inch apart. For our purposes, that means flush.

Flux is both a chemical cleaner and a protective shield for the heated metal surface which allows the molten brazing material to wet and diffuse into the parent surfaces. Such a flux can be a powder or a paste, and more recently it is applied as a coating on the filler rod. For the home craftsman the powder flux is most commonly used. (Hint: if you run out of flux, substitute ordinary laundry borax.) However, paste flux is more convenient as it eliminates the need of heating the rod and clipping it into the powder.

Capillary action will take place thoroughly if the above mentioned spacing is kept between two pieces of steel, but wider spacing will destroy the capillary effect. Heat must also be played on the area to get complete capillary action.

Making a good brazing connection is roughly the same as fusion welding, although the flame is held farther from the seam. The flame may be played on the area more than in fusion welding in order to control the temperature

1



more closely. When this temperature is correct, the molten brazing material will flow or spread at the leading edge of the puddle. If the temperature is too low, the molten material will run across the parent metal like drops of water on oil. The same thing will happen if the surface is not clean or if no flux is used. If the surface to be joined is too hot, the tin in the brazing material will burn.

A good brazed joint should be smooth and bright, with edges that blend smoothly into the parent metal. A pitted or blistery surface or an edge that seems to stand on top of the parent metal means an unsatisfactory job. This doesn't mean the joint won't hold, it just means the worker needs more practice. A very common mistake is to overheat the surface, as shown by a fine white powdery material left on both sides of the joint.

The home craftsman will find brazing an invaluable aid in all phases of motorcycle building, from making low-temperature, sheet-metal fender repairs to constructing frames. For this reason it is advisable to consult the local welding supply for the latest information on various brazing materials and techniques.

SOLDERING

In the course of maintaining one's own machine, the need for a little knowledge of soldering techniques is bound to present itself. Repairs to electrical wiring terminals at the lights, horn and instruments can sometimes mean the difference between continuing a weekend ride or being stranded miles from anywhere. Hard usage and the inevitable vibration that is present in too many of today's machines contribute to the possibility of a loose or fractured wire or terminal. A little trouble-shooting and a delicate touch with a soldering gun can usually remedy the situation.

Many, many types of soldering techniques have been developed over the years for any number of applications. Often considered to be a temporary, inherently weak joining of two materials, such is actually not the

1. A handy tool in any mechanic's garage is the soldering gun. It can be used to repair and install new electrical systems and cables. There are two basic types of solder: rosin core and acid core. Never use acid core on wiring or electricals.

2. Pop-rivet guns have become readily available and inexpensive for both the home mechanic and professional.

3. In the time of need, nothing will replace the usefulness and low cost of pop riveting. Kits are inexpensive and contain different length and diameter rivets. Can be used to install new seat covers, metal and plastic sheets and dozens of other items.

4. Just drill the recommended hole size, and then attach Dzus fastener.

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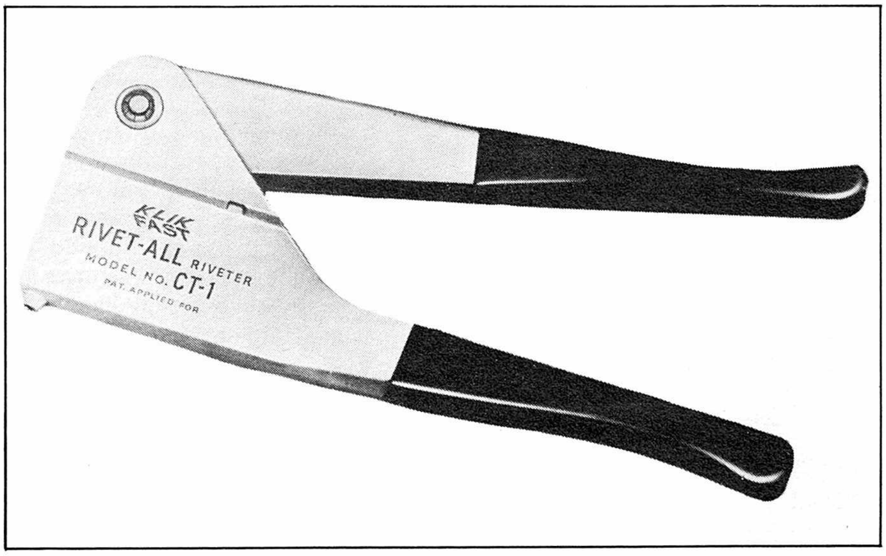

3


but again the information will probably be right on the container. As the temperature reaches that point, the solder can be applied to the point of joining. At its flow temperature point, it will do just that. It will flow right into the surrounding wires or cable strands and make a permanent bond. As soon as it flows, remove the heat and the solder; otherwise the solder will continue to flow and create a globby, sloppy-looking job. Even if it is to be hidden by components of the machine, avoid such joints since the continued heat may just have the solder flowing right out the other side of the wires. Be neat, keep the parts clean, be careful with the heat, and there are no repairs that cannot be accomplished right in your own garage. And if you do them right the first time, you will only have to do them once.

case. In the space and electronics industries, new types and qualities of solder have been developed that rival seemingly much more sophisticated processes such as gas or electric welding. However, for our uses, which are limited to the aforementioned wires and things such as control cables, knowledge of the simplest form of soldering is actually all that is required.

Basically, soldering is a joining process that attaches two or more components through the use of a third material, the solder, that flows at relatively low temperatures as compared to the other forms of material joining. This enables joining of small items such as electrical wiring without the application of temperatures that could well destroy them.

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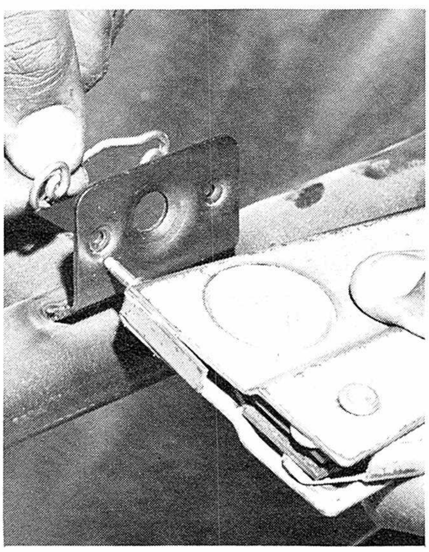


Special types of solder are available for joining everything from alloys to cast iron, although our needs will be covered by the more generally available types. However, it is wise to check the type of solder you purchase to be sure that it is suitable for the type of work you intend to do. The containers usually list the uses they are intended for, but if they do not, consult the particular manufacturer's catalog before starting work.

With the acquisition of a soldering iron or gun, which will have specific instructions for using that particular one—something we have to generalize about in a story of this type—you are ready to try it out. Select some scrap wiring for a starter and then progress to the actual repairs once you have become adept.

The single most important part of any soldering operation is to be sure that the parts are not contaminated. They must be as clean as a baby's you-know-what if they are to be joined permanently. A wire brush, or some steel wool will get them as clean as you want them, but you can ensure that things stay together by using an "acid core" solder. There is a cleaning agent right in the solder itself and when the heat releases it, it finishes the job of cleaning. A quick-and-dirty job done with this type of solder will probably hold, but it is still best to clean things first.

With the cleaning done, the parts to be joined must be heated to a point at which the solder will flow. This point will vary with the type of solder

RIVETS

Rivets have come into wide use during recent years, with the introduction of "blind" riveting techniques. First of these were the pop-rivets, so named because a charge was used to explode the rivet's blind side. Heat was a necessary factor with such units.

The newer cherry-rivets have eliminated the explosive charge and are in very wide use for a myriad of applications. The home craftsman will find cherry riveting-type pliers available at discount prices, but these cheap pliers tend to wear out rapidly. The more expensive tools sold by auto parts stores are recommended.

Blind rivets come in various diameters and lengths, but the application is the same. A hole is drilled in overlapping metal and a corresponding diameter rivet is inserted. The pliers grip a protruding "nail" and upon pressure pull the nail through the soft backside of the rivet. This expands the rivet diameter and backside, resulting in a very tight joint connection. These rivets are especially effective when joining dissimilar metals, such as an aluminum mount of a custom oil tank to a steel frame bracket. A detailed look at your machine for spots where rivets can replace nuts and bolts often eliminates losing them from vibration—like on license plate brackets or taillight mounts.

It'll take some bread, and lots of time to gain experience, but the do-it-yourselfer who can weld, solder and rivet with quality will be a lot more than just a shade tree mechanic.

TUNING BY TELEVISION

The oscilloscope is to the mechanic what X-Ray is to the physician, an invaluable picture of what's happening inside the patient. As a mechanic, beginning or advanced, you owe it to your patient to read this article

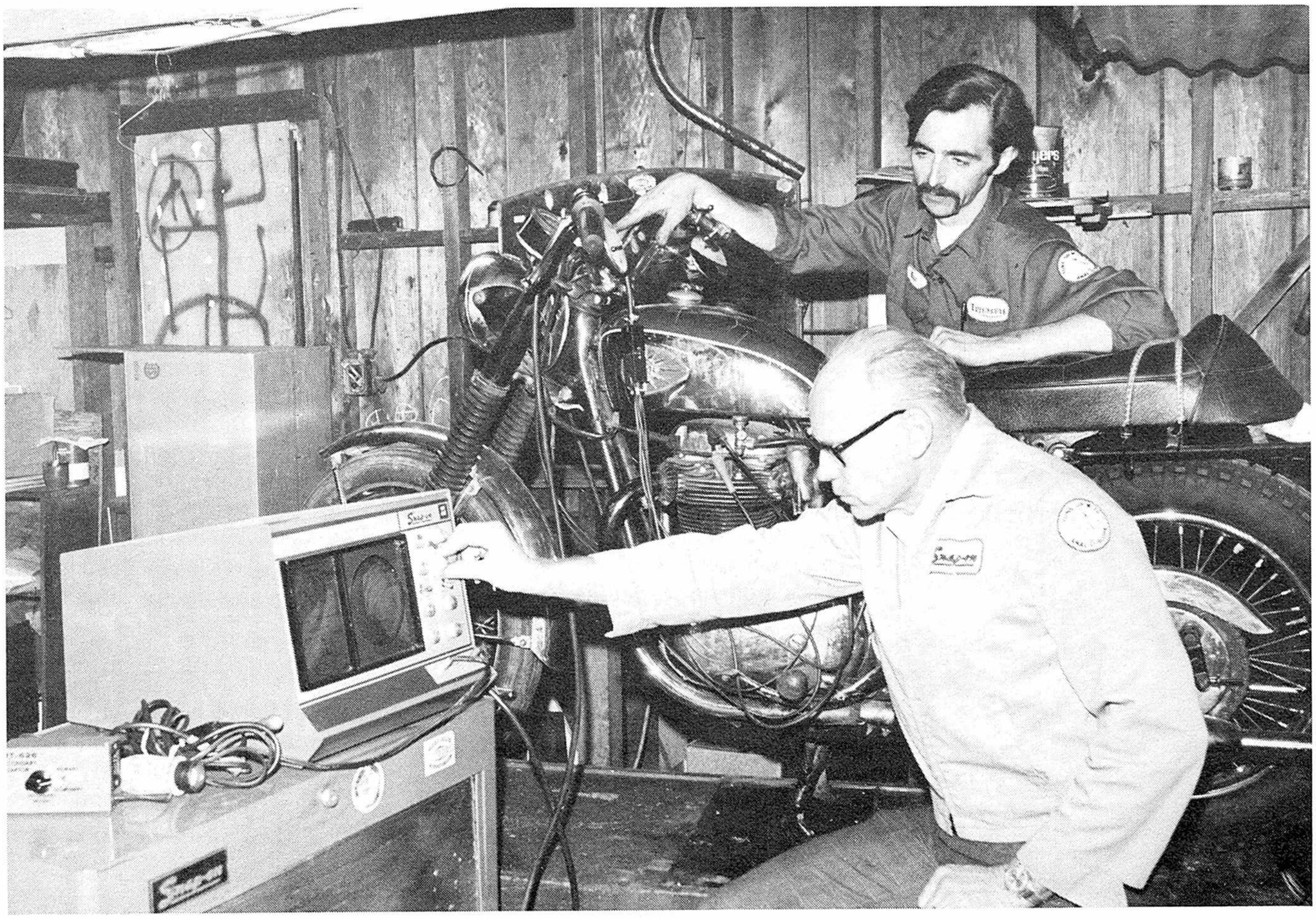
BY JOE MCFADDEN

Electronic Ignition Analyzers—better known by their nickname, "Scopes"—have been around for well over a decade now. A common sight in the lube bays of corner gas stations, new car dealer service departments, or the engine research labs of Detroit, they've proven to be the most valuable diagnostic tool known to engine technology. With unerring accuracy they pinpoint ignition problems or indicate abnormal compression situations, all within a few moments. Thereby saved: hours of valuable labor time and the exasperation of futile effort.

In operation, the pump jockey, mechanic—or engineer—swiftly attaches a few easily connected leads from scope to ignition circuit. The engine is started (or merely cranked if it won't fire), and a pattern of lines appears on the scope's screen. The pattern is an actual, instantaneous graph representing the precise movement of the electrical forces in the ignition circuit during each ignition cycle. A pulsating beat occurs with the firing of each cylinder: The knobs on the scope's console serve to allow the operator to view all cylinder pulses simultaneously, isolate a particular cylinder's ignition waveform for undistracted observation, or enlarge the picture to provide a closeup study of any part of the pattern. A normally operating ignition system provides a waveform of normal appearance; a given defect in the system will cause an abnormal appearance of the pattern in a specific area. Bad breaker points, fouled spark plugs, defective condensers, loose wires, malingering coils: all these and more are child's play to the scope. All create an abnormal appearance of the pattern lines. With experience—or more aptly, practice—chart consultations become an occasion of diminishing necessity. The "sine language" in which the scope converses is easy to learn.

In view of its virtues, or perhaps despite them, the motorcycle service industry has shown an unseemly disdain for the scope. They are regarded as oversized, super-priced, complicated and ostentatious gadgets which might make good set decorations for a science fiction movie but generally function as a vacuum device for the pump jockey's tune-up business. Although none of these impressions contain one whit of the truth, such thinking is understandable in light of this environment.

What then, if anything, can the Ig-



nition Scopes do for the motorcycle service industry? Consider the experience of Port City Honda, Wilmington, California, which installed a Sun unit 18 months ago. Service Manager John Binkley informs us that a Honda Four may be completely diagnosed in about three minutes. The conservative Flat Rate book allots an hour for the task. Port City's unit routinely saves 40 man-hours per week of troubleshooting time among three mechanics. Nearby dealers send their lemons to John, and this source accounted for a $2000 swell in the shop income over a three month period.

Foreseeably, residual benefits of scope use extend to the parts room. How many good (and costly) ignition components have been carted out of motorcycle servicings' back doors—ignominiously deposited in greasy trash cans—we couldn't say. The figure must be astronomical. Such has been the extent of our archaic "guess again" troubleshooting that has had a fertilizing effect on the back-order situation. A large share of wasted parts is contributed by mechanics who routinely replace such "expendables" as condensers in the course of a tuneup. A pair of condensers can run $8.00. Using a scope before proceeding with the tuneup will assure the mechanic of the condition of such items; for if they show up good on the screen, new items will hardly provide better performance.

Time being of the essence to flat-rate mechanics, we needn't discuss the extra minutes consumed by road testing. Verifying tuneup work right there in front of the bench is just another routine scope function. By now it should be obvious: The scope pays its freight in the course of routine chores. As for the hairy ones, well, with a scope around there aren't any.

The heart of an oscilloscope is the Cathode Ray Tube (CRT), which is a very special sort of vacuum tube. The cathode element in its neck boils off a stream of electrons when its heater is activated; the grid and anode elements just beyond concentrate the electrons into a beam and accelerate them toward a phosphorescent screen. The cathode, grid and anodes comprise, effectively, an electron gun; the screen provides the target for it. Where the beam strikes the screen a small spot of light glows. The deflecting plates alter the trajectory of the beam, which responds to the voltages which are placed on the plates. Since electrons are negatively charged particles, they are repelled by negative voltages and attracted by positive voltages.

Circuits inside the scope produce constantly varying voltages on the horizontal plates. The voltage on the right plate (inside) is made to increase in a negative direction, repelling the beam, while the voltage on the left plate is made to go positive, pulling the beam across the screen toward it. The result is a line on the screen, created by the moving beam of electrons. When the beam reaches the left side, the voltages are instantly reversed, sending the beam back again, when the process is repeated. The movement is called a sweep.

In the Ignition scope the sweep begins when the spark plug fires. As the beam moves (from left to right facing the screen), the ignition voltages are presented on the vertical plates, and the beam responds by moving up or down—according to the strength (amplitude) and polarity (direction) of the voltages. In this manner an actual photographic display, or graph, of the ignition voltage pulsations is presented on the CRT's screen—as they occur. The waveform is monitored by the scope, but its appearance is created and governed only by factors which affect the ignition circuit itself.

Ignition systems comprise two separate electrical circuits (per coil): the low voltage primary circuit, which converts a fairly long pulse of battery voltage into high-intensity magnetic energy, and the high voltage secondary circuit which converts the magnetic energy back into an electrical force that is thousands of volts strong, but brief (.0016-second) in duration. Each circuit generates electrical waveform motions of its own. Viewed on the screen of an oscilloscope, such as our ignition analyzer, the visible patterns greatly resemble one another, and indeed they should as they are created by the same trio of elec-

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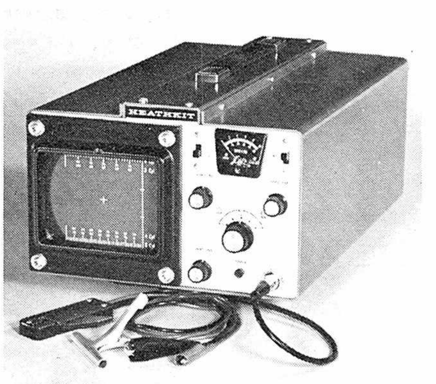

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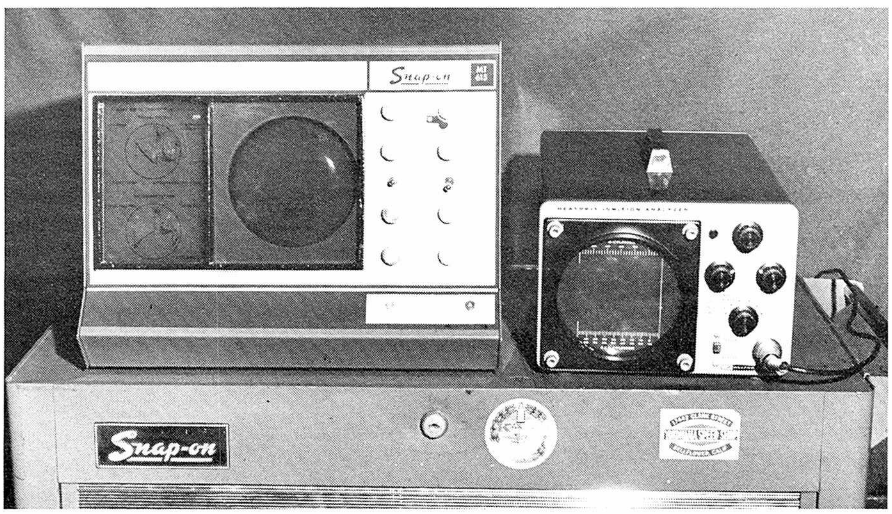


1. The Heathkit ignition scope is a terrific bargain for the low budget shop or home enthusiast. It's a do-it-yourselfer, but takes little time and practically puts itself together.

2. This is all the set-up that's needed to give you a picture of the condition of points, plug, coil, condenser, and general engine running characteristics.

3. The light and the heavy. The Snap-on scope is intended for professional use and is backed by a nation-wide training and service network. Its price is matched by its capabilities.

trical events. The action occurring in the low-voltage circuit (primary) may be observed in the Primary Pattern, that in the Secondary (high-voltage) circuit is studied in the Secondary Pattern.

Both ignition patterns are divided into three zones; each zone represents a particular electrical phase of the ignition cycle. These, designated by lettered sections in Figures 2, 3-A and 3-B, are:

1. "A", the Spark Zone, begins at point opening, describes the voltage motions which follow and ends when the spark plug stops firing.
2. "B" is known as the coil condenser zone, or Intermediate Zone. It begins when the plug stops firing, reveals the oscillations of residual coil energy between the primary winding and the condenser, indicated by the diminishing waves in the line. This zone ends when the breaker points close.
3. "C" is the dwell zone. It begins as the points close, and signifies the electromagnetic charging of the coil. Dwell, or "cam angle" as it is sometimes called may be directly measured by the number of calibration marks directly beneath its length. (Yes, you can use it to set the distributor points.) The dwell zone ends when the points again begin to break, initiating a new ignition cycle and another pattern.

Secondary patterns are used more frequently than primary patterns for several reasons. To begin with, they contain much more than basic information about the ignition: among the secondary patterns's data content are such relevant factors as cylinder compression condition, actual spark action, carburetion effects, inconsistencies in the timing and more. Primary patterns are fairly well limited to affairs on the low-voltage circuit, although primary problems will appear in the secondary pattern as well. Primary patterns are handy when there is no secondary signal, and therefore no secondary pattern to study. In addition, when primary circuit connections are not immediately available—as often as not in motorcycle application—secondary patterns are obtained by simply connecting the scope to a spark plug wire, and these are nearly always hanging out someplace. In light of its convenience, utility, and idiot-proof hookup, the secondary pattern will be first in line for the what's-goin'-on treatment.

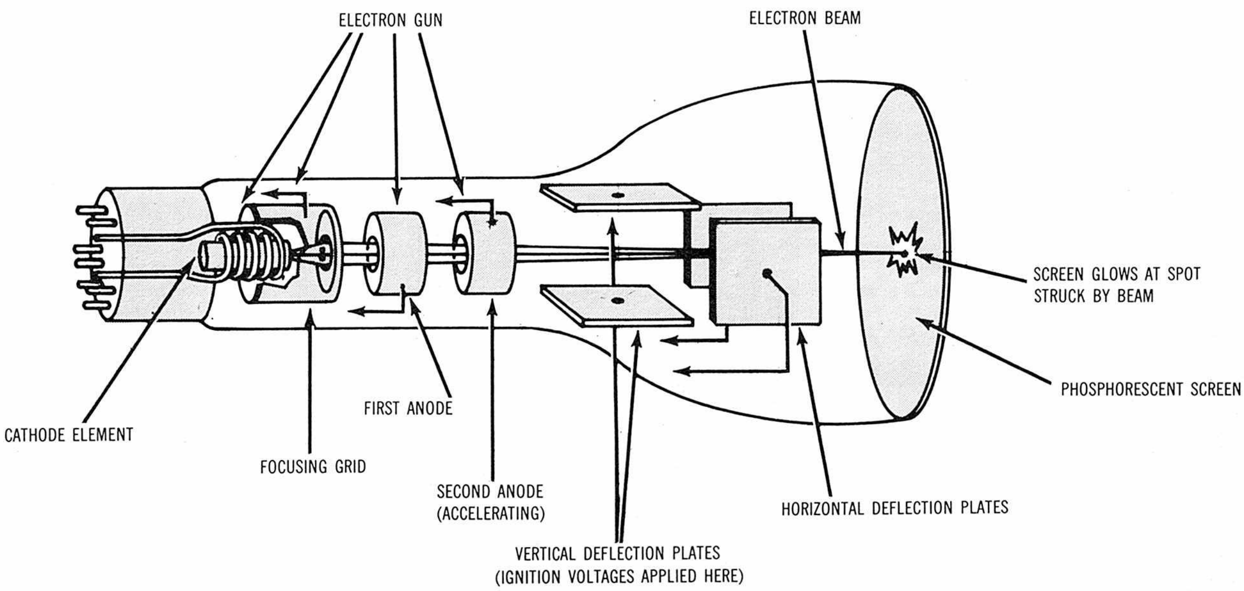
The Secondary Pattern

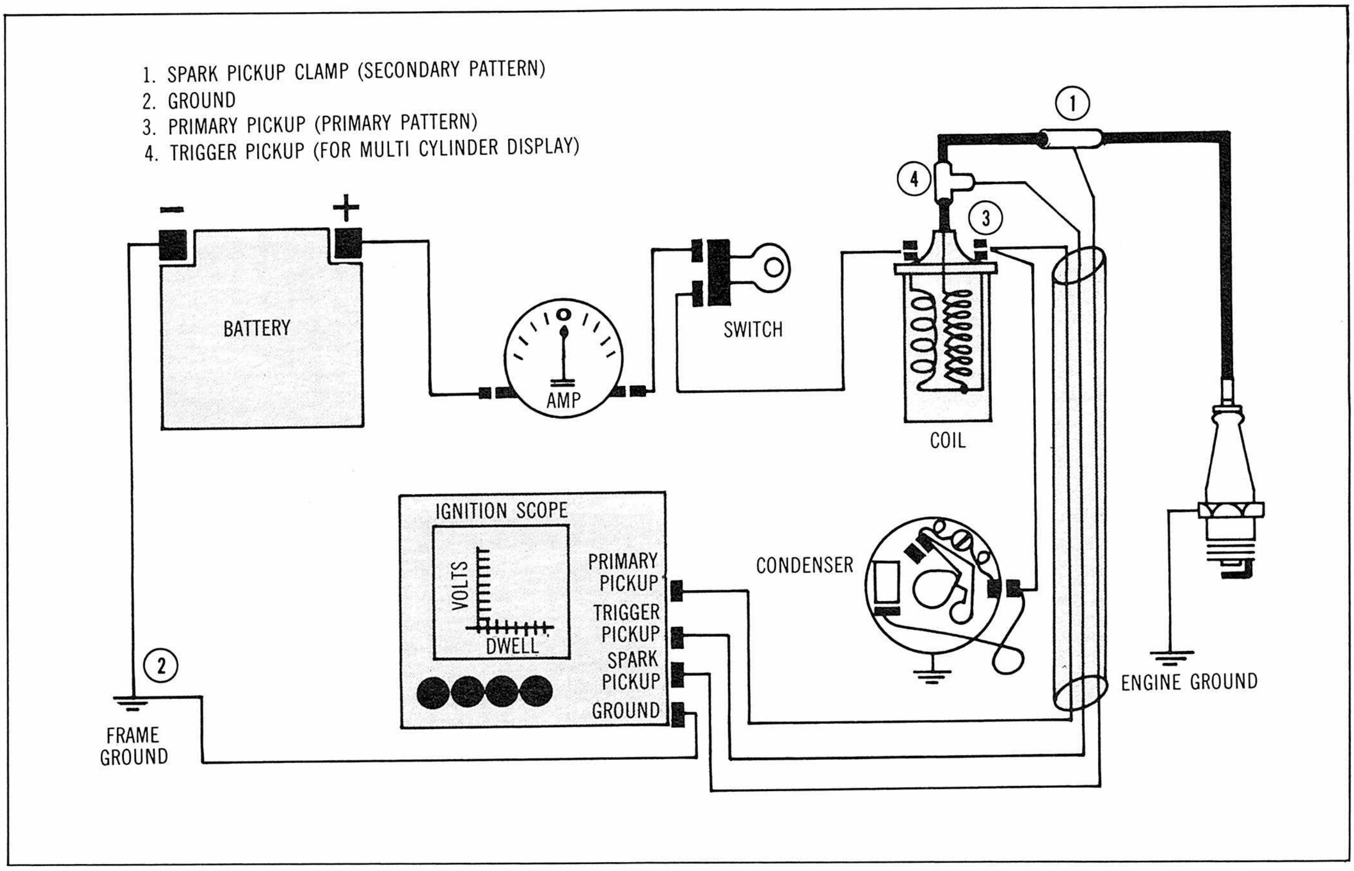
The drawing in Figure 2 is that of a more or less normal appearance of a Secondary Pattern. The action it describes will be easier to grasp if we mentally trace the image in the same way it is drawn by the scanning beam of electrons in the Cathode Ray Tube. Bear in mind that the line is a single trace which is constantly in a left-to-right motion, and does not cross the same point twice, nor, regardless of appearance is the line ever in an absolutely perpendicular position. Changes in voltage, no matter how swift, consume time as represented by horizontal motion in the pattern.

Placing an imaginary pencil at one in Figure 2, we are at the zero-volt level of the pattern. The coil is magnetically charged, and the points just break. Now the line moves upward, very rapidly as indicated by its steep vertical positioning, to two in the drawing. The voltage induced into the coil's secondary winding is felt at the electrodes of the spark plug. The plug, however, contains a quantity of compressed air between the electrodes, presenting very high resistance to electrical conduction. The circuit is momentarily incomplete, or open. In order for air molecules to conduct a flow of current, they must be "ionized," by charging them with a sufficient electrical pressure (voltage), and this value is reached at two. The line from one to two is called the firing line. Ionized air molecules heat to the point of glowing, and this ignites the fuel charge in the cylinder. The visible arc across the plug's gap is the ionized path of conduction for a very small electrical current.

Once ionized, the compressed air molecules require much less energy to sustain the process. The drop in voltage is seen by the downward path of the line from two. The spark voltage surges across the gap in a series of pulses, and the rapid fluctuations in the pattern show this as a series of short steep waves. At three, there is no longer enough energy to sustain the ionization (spark) process, and

FIGURE 1





Ignition circuits are pretty much universal and this enables scope hook-ups to be fairly simple. Power for the scope itself must be supplied separately (usually 110v. AC). For a quick, overall check of engine and ignition conditions, connections one and two only are required.

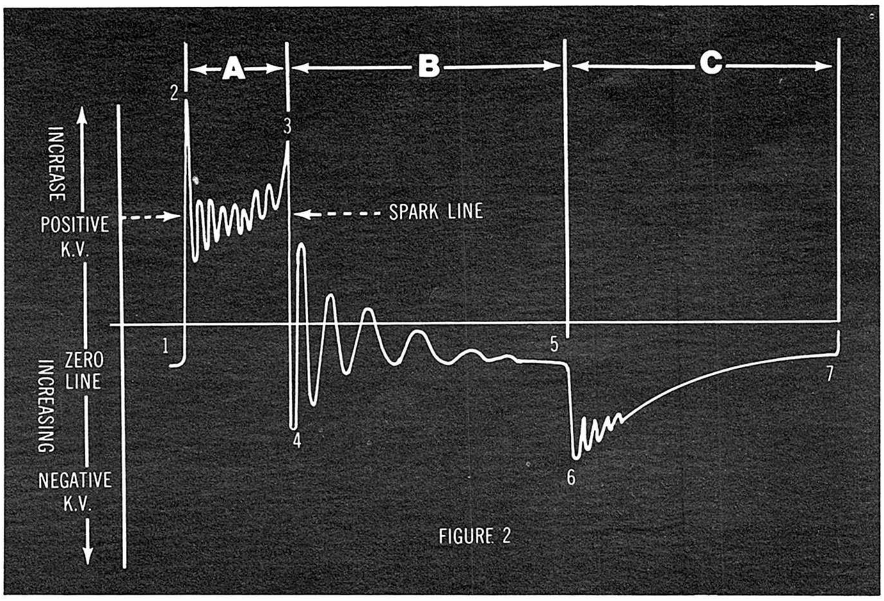


FIGURE 2

the plug abruptly quits firing. The average level of the spark signal is known as the spark line. Variations in its height will be caused by variation of the compression pressure or the spark plug gap. Increasing either will increase the height—required firing voltage—while a lower position of this line will be indicative of lower compression, and/or a tighter plug gap. Point two in the pattern may represent 10,000 volts more or less; the spark line will represent an average of 3000 volts. The figures vary greatly in practice, depending upon the engine (two- or four-cycle), compression, ignition system design, and so forth. Motorcycle applications will require the operator to note these figures himself, obtaining them from sound examples of the make with which he is most concerned. Eventually, no doubt, these specs will be made available by the manufacturers, but nothing of the scope's versatility is lost without them. Indeed, there is more to be learned—and remembered—in developing your own figures, a task which can be rewarding in many ways.

At three in the pattern, the decay line begins its rapid descent; the coil's induced energy, though no longer capable of sustaining spark, is still not quite out of steam. Its rapid collapse produces a negative going voltage within the coil, viewed in bottom sector of the decay line, which shows that the voltage has not only fallen off to zero, but begins to "rise" in a negative direction. This motion has caused the condenser to be charged anew by the resultant electrical energy produced in the primary winding. The condenser sustains its charge until four, when the induced voltage movement ceases; it then discharges this energy to the coil primary winding, again placing an electromagnetic charge in the coil. This may be observed in the upward swing of the signal from four. When the condenser has dissipated its energy, the magnetic charge it developed in the coil primary winding commences to collapse, inducing another surge of voltage in the primary aimed back at the condenser. Once again coil voltage

charges the condenser, and once again the condenser discharges, recharging the coil. This is known as oscillation, and the wavy lines in the intermediate section indicate the rising and falling voltages which result. Each exchange of energy between the coil and the condenser requires the expenditure of some of that very energy. Momentum is lost, and the surges diminish, noted by the reduced height of subsequent oscillation waves. The total effect is known as a "damped oscillation," and thus we have the reason for the appearance of the line between four and five. The sloping of the upright portions of the ebbing waves in the coil/condenser (or intermediate) zone indicates the relatively slow manner of the energy oscillations. The line has faded into a straight portion just prior to reaching point five, from which we may safely establish that the oscillations have ceased, and there is a brief period in which there are no pulsations of any kind taking place within the ignition circuit. We'll soon see that defects of any kind associated with the action of the coil and condenser will radically alter the appearance of this line (from four) if not evidenced as well elsewhere in the pattern.

At five, the points have just begun to close in the primary circuit, and the rising primary current produces a voltage of opposite polarity within the secondary. For this reason, the line drops sharply at five, as the sudden reverse surge is induced in the secondary. Before the coil can become magnetically recharged, it must overcome the residual polarity of the iron core within the windings. Some vibration is felt in the burgeoning magnetic lines of force, and the effect is called coil "ringing." We observe the ringing in the small wiggles which comprise the rest of the points closing signal, and as the coil's electromagnetism stabilizes and grows, the wiggles blend into the curved voltage line which indicates the deterioration of the induced voltage in the secondary: For a signal is only induced by voltage *changes* in the primary. The line from five to seven then, comprises the dwell zone portion of the pattern, and as previously mentioned, we can utilize this line in the calibration of the point gap, or dwell angle setting, thereby eliminating the inconsistencies of feeler gauge adjustment techniques. The elusive maladies created

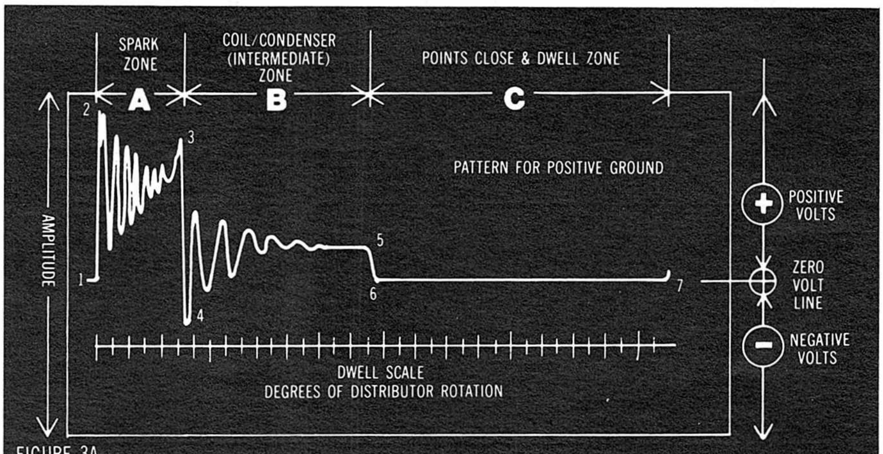


FIGURE 3A

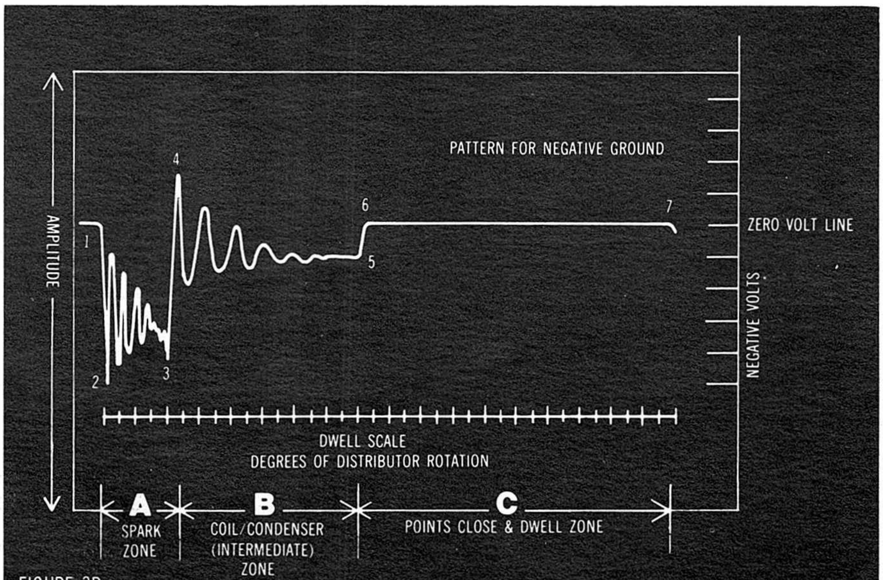


FIGURE 3B

by bouncing (or sticking) points are immediately evident in the curving slope of the dwell line. Points which require replacement are evidenced in the altered appearance of the "ringing" wiggles. If these wiggles, on the other hand appear normal, you're wasting time and money to exchange the resident components.

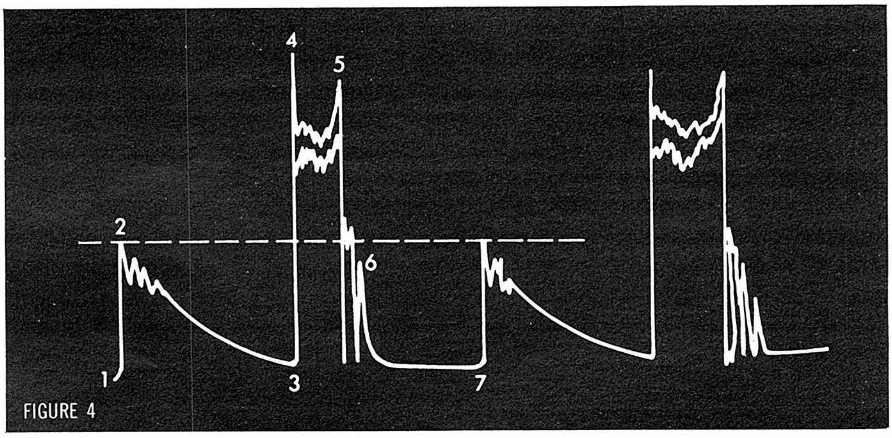
At seven, we see the birth of a new ignition cycle, terminating our pattern and the threefold electrical sequence which created it. The vertical tail is the opening of the points, and the beginning of a new firing line. Distortion of the section at seven would of course tell us that we have a point opening problem, as might be caused, for example, by point arcing or faulty battery or distributor ground connections.

If the theories involved in the development of a Secondary Ignition Pattern seem beyond your complete comprehension, or immediate memory, fret not. As long as you have an idea of which events are taking place in the three zones, and an approximation of the appearance of a normal pattern, you'll only need a list of pattern deviation drawings which accompany every scope to be ready to go. With a bit of practice you'll soon be the local ignition whiz, detecting the hairiest of hairies, and basking in the glow of the Melvin McKannick-buggers' adulation. Don't even try to tell 'em it "Wasn't no big thing"; they won't believe it.

The Primary Ignition Pattern

Primary Patterns describe the very same actions we related in the explanation of Secondary Patterns, with but minor differences. We should immediately recognize the three zones within the pattern, and careful study will reveal but two differences; these within the spark zone and the dwell zone, particularly in the points close signal. The differences merit a closer look, and discussion.

The primary pattern height will, in practice be presented in the same size



The appearance of the Snap-on primary pattern differs from the standard waveform due to the fact that it is the signal pictured across the coil primary rather than across the points. At 1 the points have closed and at 2 we see the ringing signal usually found in secondary patterns. From 2 to 3 is the dwell zone and at 3 the points have opened. The firing line and spark zones (3, 4, 5) appear as in normal patterns, but the condenser oscillations are presented above the zero reference line at 6. At 7 the points are again closed, beginning another cycle. Differences in dwell line height indicated by the dotted line, show distributor faults. Ground faults and primary defects show from 1 to 2 and at 2 to 3 respectively.

as the secondary pattern. The voltage levels represented are vastly smaller, however, representing peaks of several hundred volts or less, induced within the primary winding by the collapsing energy field. The similarity of the patterns' dimensions are an accommodation to easier viewing by the circuits within the scope.

Again at one we have the beginning of the firing line (Figures 3-A and 3-B) as the collapsing charge of magnetic energy induces primary voltages far in excess of the static battery levels of six or 12 volts. This voltage is felt "across" the points, which are now open. As the spark plug begins firing, at two in the primary pattern, the primary winding of the coil begins to interact with the condenser—just as we discussed in the coil/condenser section of the secondary pattern. The result is a series of rapid oscillations in the coil primary, serving to sustain the spark signal, for these oscillations are felt in the spark line of the secondary pattern.

The primary oscillations, dampened, cease at three when the spark plug stops firing, for reasons previously covered. Again, as in the secondary, the decay line appears, from three to four, and the coil condenser action is renewed by the renewed induction of energy created by the residual coil charge. The oscillations beginning at four occur in the primary but are reflected in the secondary, creating the coil/condenser zone in both patterns.

At five, the points have just begun to close, and here we see a difference in the pattern's appearance. The dropping line signifies the points closing, as mentioned, but in the primary pattern this drop began from the battery voltage level—which the scope felt as the difference in potential between the coil's primary-to-distributor connection and ground. The drop ends at six in the primary pattern, where the scope no longer senses any difference in potential between the now closed point contacts. Thus the line from six to seven, the dwell line, as you may already be aware, is in essence a zero-volt reference level. Current is flowing steadily through the coil, and the newly blossoming lines of magnetic induction, being created by the primary winding, have no effect upon the stable direct current (D.C.) flowing through the primary ignition circuit. At seven, again just as in the secondary pattern, we have the beginning of a new ignition cycle.

Prior to our explanation of secondary patterns, we made several observations which might have lead the reader to believe that primary pattern study is almost a waste of time. This isn't quite the case. Our references were intended for situations where, for example, a quick estimation of the ignition shape was essential, such as a pre-tuneup check, where we might want to know if it would or would not be prudent to replace the points, condensers or spark plugs. Secondary patterns are the obvious choice for such purposes, but where and when the primary circuit connection points are available, the extra moments of hookup time are worthwhile, as is the study of the primary pattern itself. The clarity of the points close signal makes the primary pattern a desirable choice in making point gap adjustments. In situations where the coil is not firing and the motor won't start, the primary pattern is a fortunate, if not only, convenience short of the impact wrench, service tester and a bunch of time at hand. Providing current is flowing in the primary circuit, the primary pattern will tell us why we have no secondary pattern (spark).

The scope's versatility is extended by its primary circuit connections: By connecting them to our alternator output wires we can examine the source of the charging function of most motorcycles. (A connection must also be made to one of the plug wires to trigger the presentation.) Defects within that system will likewise make themselves visible on the screen. There isn't sufficient space to discuss this application here.

The primary pattern illustrated in Figure 3-B is a negative ground type. These normally appear inverted, while positive ground ignition waveforms appear upright. Reversed coil polarity is indicated when either type of pattern appears inverted from its normal direction.

A rather unusual Primary Pattern display is seen on the Anal-O-Scope sold by Snap-On Tool Corporation; and the pattern is illustrated in Figure 4. Chief reason for the difference in waveform appearance is the fact that the signal is taken across the coil primary winding, rather than across the points. The scheme has several advantages: The operator can immediately establish the source of poor circuit connections, whether in the primary supply or primary ground. Abnormal distributor action is easier to detect (by comparing the height of the cam angle lines) as caused by worn distributor shafts, bushings, and so on; although this function is certainly of far more use to the four-wheelers. Ignition defects, however, appear in precisely the same manner regardless of how the pattern is presented. Presentation differences are merely accents, the sine language remains the same.

Presentation Of Patterns

Patterns may be displayed in one of three different ways, and selection is made by operating a knob on the scope's console.

Parade: The parade function allows

us to view all cylinder patterns simultaneously. The patterns appear in a horizontal row. They may be expanded so that a single pattern occupies the entire screen for a single-cylinder display, much enlarged and easy to study. The whole of the waveform may be moved to the left or right, bringing the next pattern into view for closeup study, just as though it were a strip of film passing through a magnifying viewer, which we could pull toward either direction at random. Our subject patterns include several parade presentations. Naturally we can select either primary or secondary patterns for parade presentation. The vertical control provides for up and down positioning of the patterns.

Superimposed: This display lumps all available patterns into one presentation, similar to a double exposure effect in a camera. It is an effective method of detecting erratic distributor action, evidenced in multiple point close signals appearing. Some coil problems are manifested best in this type of pattern.

Raster: Also known as a stack type of presentation, this form of display is not available on all oscilloscopes. The separate ignition waveforms are presented in single patterns, which are placed, one atop the other, in a vertical row. Simultaneous detail study of all patterns is thus possible, since full use is made of the vertical space on the screen. In both raster and parade modes, a trigger pickup device is attached to the plug wire of a given cylinder. That cylinder will then be the first pattern on the left (parade) or the bottom pattern (raster), with the following patterns representing the cylinders in the appropriate firing order. Single-cylinder patterns, such as might be obtained from a single-cylinder motorcycle engine, of course are only displayed as a single pattern, regardless of the mode selected.

Troubleshooting With the Scope

Now let's go troubleshooting with the scope, to see just how simple and obvious those ignition bugs can be. Figure 5 is a parade display, and the left cylinder pattern appears on the left. Quite apparent is the reversed polarity evident by the appearance of the right-hand ignition pattern—upside down. Reversed polarity requires 20 to 40 percent more voltage to ionize the plug gap, and the difference in the pattern amplitudes is significant. You might have noticed that the points close signal following the left-hand pattern is that for the right cylinder—the left side ignition points are actually still open. Following the right side pattern, the points close to begin the dwell period for the left.

Having corrected the reversed coil connections in Figure 5, we decided to stick with the subject and test the ignition coils—a quick, simple, and accurate matter with our scope. Removing the left cylinder spark plug wire resulted in Figure 6. What we're looking for is the maximum coil output, and by removing the spark plug wire we make it work as hard as it is capable of doing. A good coil will produce a pattern of at least double the amplitude attained in normal operation. Our left side coil is an obvious winner. Less than twice the normal size pattern would indicate low battery supply voltage to the coil, or a bad coil. The D.C. voltmeter would finish the story. Measuring from the coil battery connection to ground should give a 12 (in this case) volt reading. Given 12 volts there, we'd have a bum coil. Less than 12 volts at the coil primary connection would mean a low battery, or a bad connection between battery and coil. (Check ignition switch and wiring harness snap connectors.)

Repeating the coil test on the right side we see a pattern of proper amplitude, so our coil is good. But a spark line we shouldn't have, for our wire has been removed from the plug. Cause? Faulty wire is arcing to frame.

Proceeding with the fun, we expand the trace to obtain an eyeful of a point close signal (Figure 8). If you paid close attention to the secondary pattern explanation, you've already estimated—correctly—that this set of points is out to lunch; the first wiggle is not hanging lower than the subsequent wiggles, and if that isn't easy enough to remember, neither is your birthday.

In Figure 9 we see what a faulty point opening does for the pattern. The break in the firing line is caused by point arcing, or flashing. This malady is a symptom, however, more than a cause—for when we look at the intermediate zone we notice a reduction in the number and size of the coil/condenser wiggles. The condenser in this case had a bad case of insulation breakdown, but there is really no need to go into that subject, just throw away the condenser. Figure

FIGURE 5

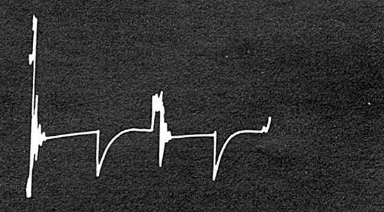


FIGURE 6

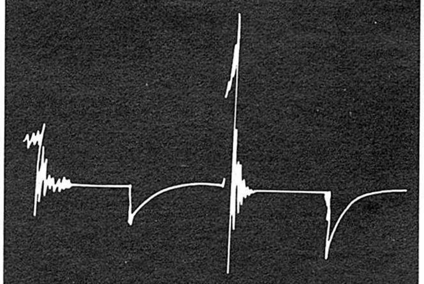


FIGURE 7

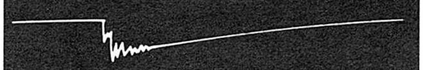


FIGURE 8

FIGURE 9

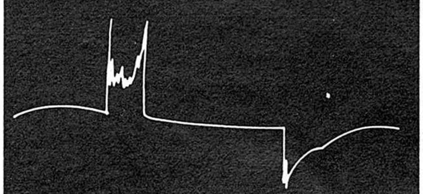


FIGURE 10

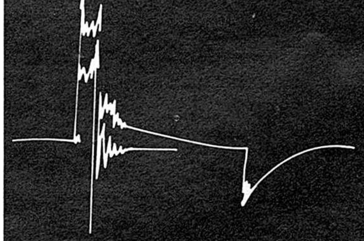


FIGURE 11

FIGURE 12

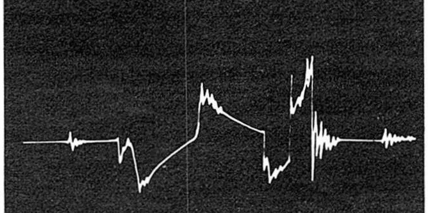


FIGURE 13

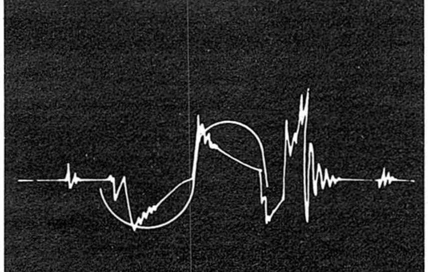


FIGURE 14

10 is what happens when you *do* discard the condenser, and forget to put another one back in! On the other hand an open condenser, or broken condenser lead will produce the same effect. Last, but not the least likely source of such an effect (you do notice the lack of oscillations in the intermediate zone?) would be a coil.

A common tuneup problem, and one which is invariably missed during the "r and r" episodes, is literally brought to light in Figure 11. The cause of this nervous pattern was a corroded spark plug connector, securely hidden otherwise in the rubber plug cap. Although we didn't plant this one, you can see why it didn't sneak by. If you ever see this one again, don't rule out a *loose* plug wire as a second possibility.

Figure 12 is a primary ignition Pattern. The bumps in the intermediate zone led us to think the rectifier was leaking some alternating current (A.C.), alternator voltage into the circuit. To verify this, we disconnected the battery ground wire, a pardonable sin with a Lucas Zener diode on duty. Switching the scope back to secondary pattern, we fired her up. We thought for a moment we'd lost the scope (Figure 13). Regaining our composure, we realized that what we had was a totally lunched rectifier. The battery had been filtering out the worst of it, and was itself none the better for the experience. In Figure 14 we have superimposed the alternator's sine wave output which was passing the rectifier. This example of the scope's remarkable capabilities as a tuneup tool is in no way far removed from the ordinary. Had the machine been otherwise tuned, this problem would no doubt have gone unnoticed —until three or four batteries later, and possibly a demagnetized alternator rotor.

And so you have it. A small glimpse at what tuning with tubes is about. Far and away better than having a full-time factory rep in your grease bay, the scope is the most idiot-proof, the most accurate, the most infallible, and just plain the "most" diagnostic tool you can lay your hands on. With a couple of weeks' practice at it, there is no reason why any problem can't be located in 30 minutes or less, and that is a sandbagging figure if ever there was one!

It wouldn't be fair to sneak off without giving you some idea of what a scope can run you, dollar-wise, nor to leave you without any shopping guidelines. You realize, of course, that you don't just dash on down to your corner drugstore and order one, so here's the deal on at least three of them.

Heath Scope. Our little lightweight (12-pound) Heathkit 10-20 came to us through the offices of Heath's Earl Broihier. The Heath comes in a kit and a choice kit it is. Assembly is simple (we kid you not) and the only tools you'll need had better be in your tool box anyway—if you're a motorcycle wrench-bender worthy of the name. The kit runs about $110.00, and Heath guarantees that everything is there and will work as stated. Ours has been on combat duty for almost nine months, as witness the beer can scratches on its case! It has worked perfectly since we first plugged it in. You can obtain the Heath catalog and order form by writing Heath Company, Benton Harbor, Michigan 49022.

The catalog includes a whole bunch of goodies you won't believe unless you see. Their mail order service is unparalleled. A nationwide chain—make that worldwide—of Heath Factory Service Centers provide service when needed.

Snap-On's Anal-O-Scope is available through the guys in the red and white Snap-On trucks. If they don't stop at your shop, call them, they're in the yellow pages. The Snap-On people will send a rep down for a no-obligation demonstration of the Anal-O-Scope. The directions which come with the Snap-On scope (including the pattern charts) take a back seat to nobody. Their directions are all you need—beside the scope, of course. The unit runs about $1000.00, and comes with an integral timing light, adapters, shirt emblems, etc. It features an electronic ignition loading device which lets you road-test a tune-up while sitting (on your wheel-a-round). If the scope doesn't bring in at least five times that amount, you better close your doors, your customers all left. The infallible Snap-On guarantee covers any service problems you're unlikely to encounter. The unit weighs about 50 pounds, can be powered by 115 volt, A.C. wall juice, or a 12-volt auto battery.

The Sun Scope unit in use at Port City Honda (mentioned earlier) cost a walloping $2300.00, but included the whole system. That one paid for itself a long time ago, but the individual Sun Scope unit can be had for about $1000.00. They have so many different models that choosing is difficult; Sun runs a chain of scope schools to educate their friends and buyers. All Sun scopes feature voltage scales and the raster display, so you can measure anything in the ignition short of the plug thread reach, and no doubt they've thought about that one, too. If you seek the purchase of one of their big screen babies, (up to 24-inch) be sure to have them include adapters for multiple coil ignitions; some bikes do run more than one coil. Sun Units are marketed through factory outlets, which number 33 in the U.S. alone. If you can't find them in the phone book, write: Sun Electric Company, Harlem and Avondale, Chicago, Illinois 60631. Overseas inquiries can also be sent to the Chicago shop, but the Sun distributor network covers 116 countries around the world.

There are other fine makes around, but it would be impossible to list them all. As a rule of thumb, consider the access you might have to service and training facilities, rather than price. For the Heath Unit at $110.00 the lowest priced, nor is the $2300.00 Sun extravagant—not considering the return on the dollar. Scopes will pay themselves off faster than a Golden Egg Laying Goose, but don't take our word for it: ask any person who owns one. We highly recommend you be the first in your block to buy one.

CLUTCHES AND TRANSMISSIONS

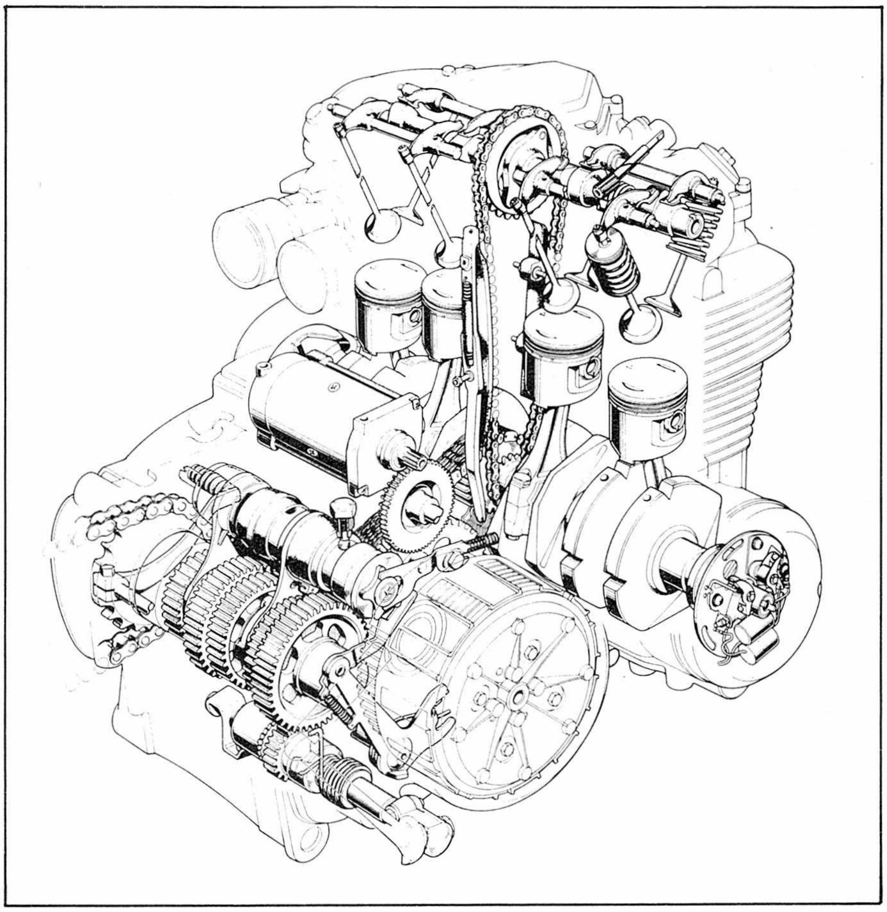
All the power in the world is useless if you can't put it to work. That is why these vital components deserve careful scrutiny

BY DAN COTTERMAN

I have a philosophy that helps me every time I sit down to fix something. I figure the guy they hired at the factory to put the thing together wasn't any smarter than I am. The fact that he knew a lot more than I do about the particular object I intend to repair doesn't throw me out of phase—not if I can spend some time making up the difference by finding out what I'm doing before I begin.

Making up the difference is what this is all about, not by giving you a bolt-by-bolt description of every clutch and transmission on every motorcycle you might encounter, but by bringing to light many of the things that apply to any repair effort. I'm talking about the little things—the tricks that may or may not be mentioned in service manuals and rider handbooks. Often overlooked by the fellow who undertakes the doing of his own repair and maintenance work, they can make all the difference.

We'll make the rounds through primary drive systems, shifting mechanisms, transmissions and adjustments. Then we'll settle (or render deathless) that old controversy about whether it's a good idea to use automatic transmission fluid in bikes. We'll talk with the people who make the parts and the people who install and repair them, starting with the clutch.



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CABLE ADJUSTMENT

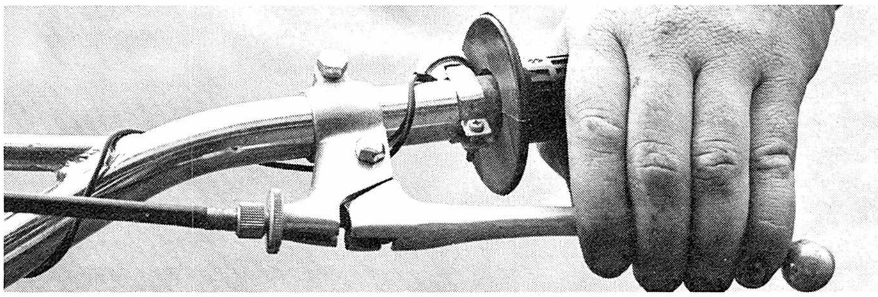
Let's attack this thing from the outside. Before you jump to the conclusion that your clutch is a goner or that your transmission won't shift, be sure the clutch cable adjustment is right. I know, it sounds all too obvious, but aren't these the things even the best of us sometimes forget? During five years as a dealer I can remember numerous instances of standing next to a bike while the owner sat there telling me how his clutch was either slipping or not disengaging enough to allow effortless shifting. With the latter situation, the transmission itself would sometimes be blamed. As the conversation went on, it was easy enough for me to glance at the handlebar end of the clutch cable adjustment. More often than not, the problem of slipping could be traced to insufficient "play" in the handle, while balky shifting was usually the result of too much free movement in the handle. Either of these extremes could be remedied by a few quick twists on the adjuster. It was even easier to smile and say, "Try it now," after which the fellow would buzz up to the corner and back to report that everything was working fine.

There is seldom any charge for that kind of on-the-spot service, no matter where it happens to be rendered. The dealer chalks it up to good will and settles for the satisfaction that he was able to do someone a favor. It doesn't become expensive until adjustment is neglected. The slipping clutch wears away the friction surface on the driven plates, glazes them over and causes more slipping. Compounding the situation is heat, which works to warp both driving and driven plates. On the other hand, the clutch that isn't adjusted so as to release properly will make shifting difficult. The extra pressure that has to be applied (due to difficult shifting) can result in misalignment of elements of the shifting mechanism and bent or broken shifter forks.

WORKSHOP MANUALS

Let's say you've done the right thing and have the rider handbook for your particular bike and let's assume you've followed the instructions therein and have carefully seen to the proper adjustment of your clutch. If these steps fail to correct the problem

it's time to go inside. Now's the time to really begin making up that difference we talked about a few minutes ago by laying your hands on a workshop manual. Study the job at hand carefully before you loosen the first screw, make sure you have all the tools you're going to need, and continue to consult the manual as you take things apart. Don't, whatever you do, start ripping things apart and tossing them in a box without regard to the order in which they were originally assembled. There's a fair chance that the particular manual you're having to use won't have an adequate drawing to indicate the correct order of reassembly. In the case of many of the older Japanese machines you may be confronted with a grainy photographic reproduction of a clutch or transmission, snapped with a wide-angle lens from some considerable distance, while its components were spread over some colorless background. Mechanical drawings are better, but even drawings are subject to inaccuracies, as we will note in the section on transmissions. Further emphasizing the importance of observing the order of parts as you remove them is the classic situation involving the manual that details the procedure for "unassembly" thoroughly enough. Then, when you turn the page to find out how to put it back together it simply says, "Reverse unassembly instructions." Friends, you haven't lived until you've tried to read Czechoslovakian-English backwards! But, regardless of the flaws you may encounter, a workshop manual is the best way to go when you're doing your own repair work. Just remember to take your time—you might even discover that someone before you has had the thing apart and put it back



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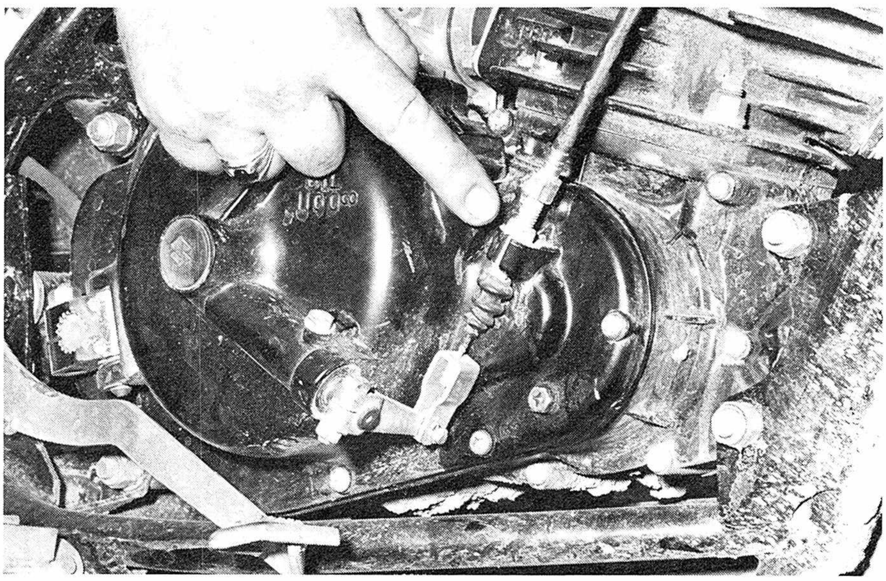

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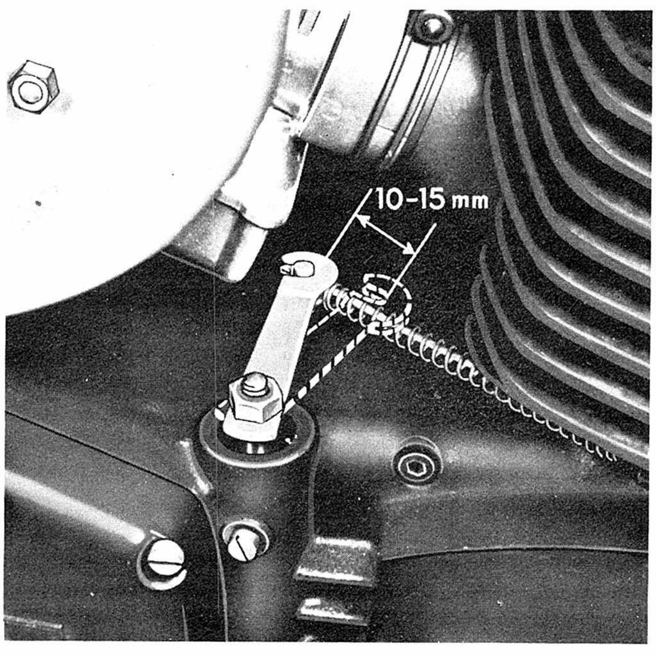

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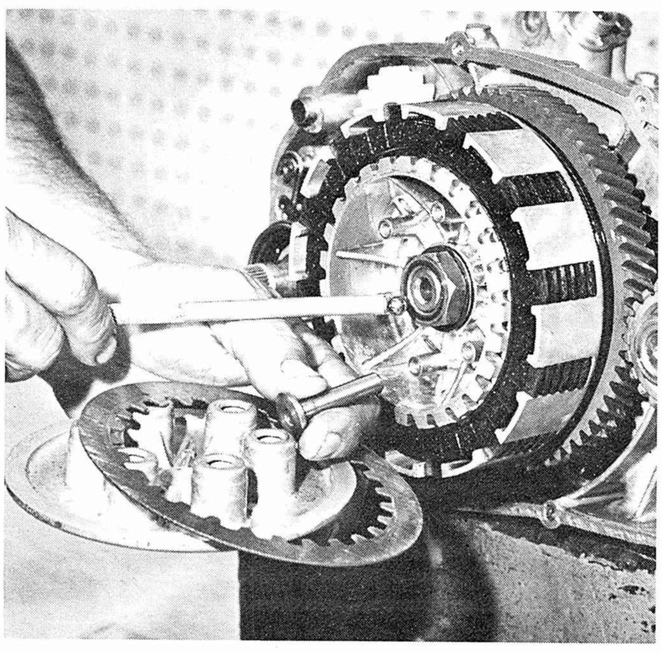

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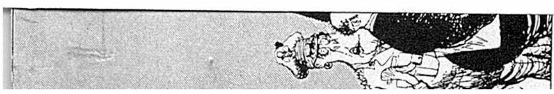
1. Sophistication has led to far more complex driveline systems for cycle engines like Honda's Four.

2. Adjustment at the clutch lever should be made with the engine at operating temperature. Normal free play at pivot opening is ¼ inch.

3. Many machines have external access to primary clutch adjustment. Adjustment should be made here first.

4. Your factory service manual should give you the proper free play necessary at external pivot arms. Recommended adjustment is amount of tolerance necessary to prevent slippage, friction.

5. Transmissions using a long crossover pushrod must have play to keep the delicate parts safe from friction damage. Remember to replace ball.



CLUTCHES

together wrong or, worse yet, left something out.

Going a step further, let's suppose you've taken your clutch apart and that the parts are carefully laid out, hopefully in the order in which you removed them. If this wasn't practical you may even have made a rough pencil sketch to show the order of reassembly, an excellent idea. The question now is what to look for. How do you know whether parts can be salvaged or must be replaced? There are some definite signs.

CLUTCH PUSHROD

We were talking about adjustments so let's take the clutch pushrod first. Naturally, it should be straight, but finding this out is kind of like buying a drumstick: The simplest way is to roll it slowly across some reasonably flat surface, not necessarily the garage floor, but preferably a piece of glass. If it wobbles while rolling you have probably found at least part of your trouble. Look at each of its ends. If either of them is mushroomed, the pushrod should be replaced. It should also be measured to be sure it is of standard length. If your manual doesn't state correct length, take it to your dealer and compare with a new one. A difference of a few thousandths of an inch can be taken up by the adjustment screw, while a sizable difference will make good clutch adjustment impossible.

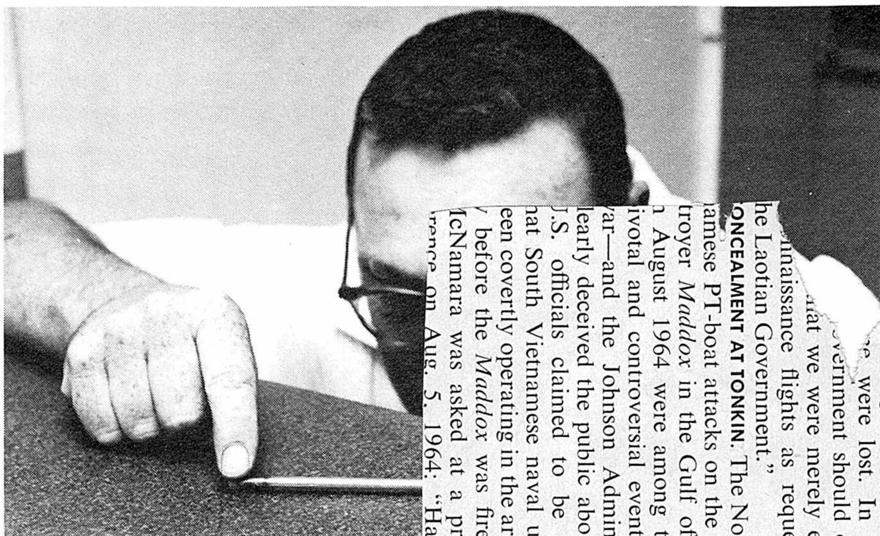
. . . AND SPRINGS

The books sometimes tell you to measure the length of the clutch tensioning springs. This method is good, but measure also the importance of these little springs against their relatively low cost. If you've any doubts, replace them all. You might even want to take a set of calipers to the parts counter with you and check several of the new springs for evenness of length. I've seen a measureable difference in the lengths of clutch springs right out of the box from the factory, so it doesn't hurt to be sure of going home with a matched set.

Matching the tènsions of these clutch springs is also of importance. Uneven spring tensioning will cause erratic clutch action and rapid destruction of the plates. If yours is a clutch that calls for running spring adjustment screws all the way in till they "bottom" it will have been enough that you made sure the springs were all of the same length. However, tensioning the springs on many motorcycles is a matter of careful adjustment. Your workshop manual will tell you how to effect this adjustment, but be sure to check your work by pushing the starter arm through while observing the rotation of the plates with the clutch lever pulled in (disengaged). Uneven spring tensioning will be evidenced by a wobble as the plates rotate. This also is a good technique for checking preliminary clutch adjustment. Pass the starter arm through with the clutch engaged and disengaged. And don't forget to remove all your spark plugs so you won't be working against engine compression.

HUBS AND HOUSINGS

I chatted with Jim Hunter, a tuner of considerable experience when it comes to British machines, and learned something that applies to many clutch repairs, regardless of where the bike may have been manufactured. Hunter was quick to point out the fact that the fellow who installs a set of new clutch plates on his own is usually in such a hurry to get everything bolted together again and back on the trail that he overlooks some rather important steps in the operation. One of these is the cleaning of the spline cuts in the clutch chainwheel. The continual back-and-forth agitation of the tabs on clutch plates in these spline cuts will eventually create little notches. Understand that when either engaging or disengaging, the clutch plate tabs must move laterally along these cuts. If the notches aren't dressed off, as with a scraper or small file, the tabs can hang up on them when you get ready for your



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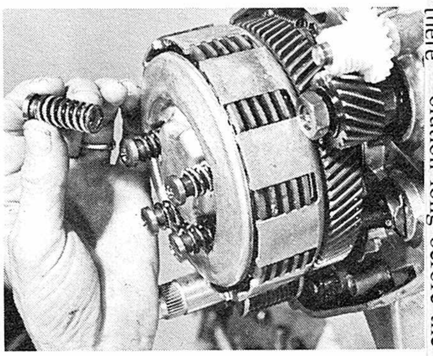

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1. While the pushrod is out, trueness should be checked. Windy Briggs of Kawasaki rolls a pushrod over a flat plate. Bent rod must be straightened.

2. Clutch spring screws on Japanese bikes are tightened to bottom. Springs may be color coded. All must match.

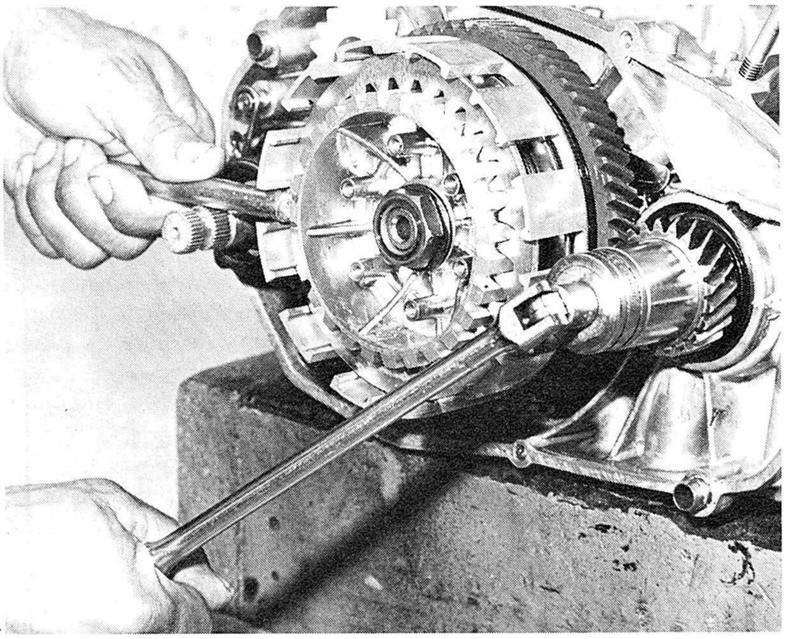
3. Using Vernier calipers is best method of checking for collapsed spring. Service manual will give tolerance.

4. Removal of clutch and primary gear nuts is easily done with special tool. Make one from old friction plate.

5. Japanese clutches with helical-cut gears have considerable side thrust. Therefore extensive use of thrust bearings, washers. Assemble in order.

6. Wet, oil bathed, clutches can use fiber on steel or steel on steel plates.

7. Engine thrust has mushroomed tabs. Must be filed smooth or replaced.



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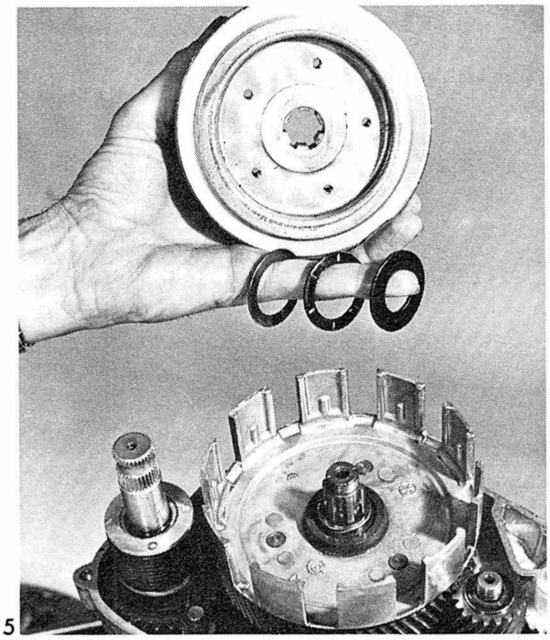

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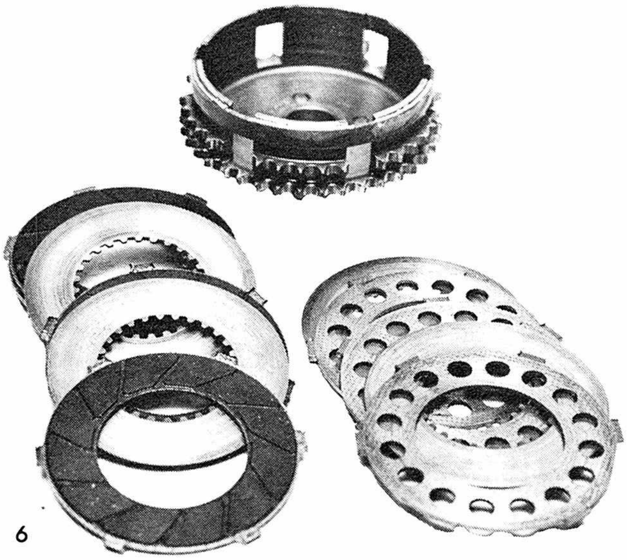

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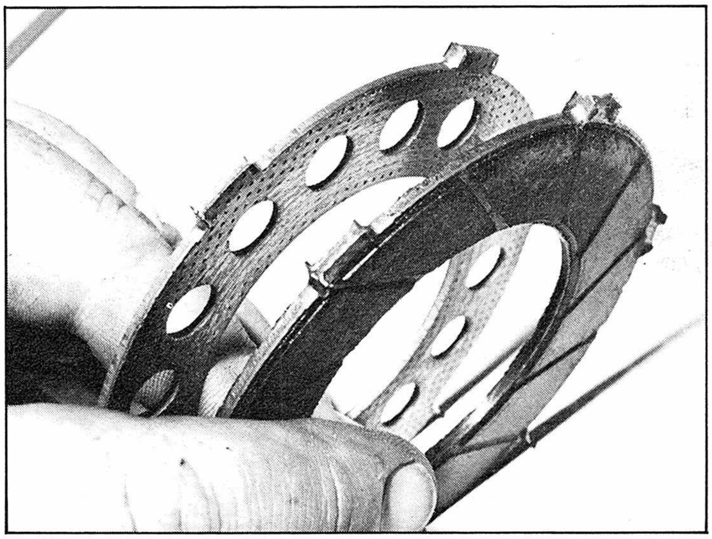

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test run and foul up what might have been a good job.

Something else mentioned by Hunter does not apply to all machines, but is infinitely worth passing along. It simply involves some attention to the tightening of three or four screws in the center hub. Particular attention was drawn to British clutch setups. If the tightening of these three or four screws (depending on model) is neglected, more trouble will result.

CLUTCH PLATES

I called Barnett Tool and Engineering for a Q & A session with motorcycling's "Mr. Clutch" and was referred to one of the organization's key men, Mike Taylor. The interview was tape recorded and it's a good thing because it turned out that Taylor expounded information on clutch plates faster than I could have scribbled it down. Our conversation was later transcribed into four pages of handwritten notes. I think you will find the digest of those notes well worth the reading!

I was interested in what material was used for the friction segments on Barnett clutch plates. With one exception, it is a composition material which is manufactured by the Armstrong Floor people. It comes in different grades and is selected by Barnett on the basis of its softness, durability under the stresses of heat, pressure and abrasion and for its resistance to swelling when saturated with oil. There is no difference in the material whether for dry, wet or so-called "oil-bath" systems.

The difference in material comes with dry plates for super-torquers like the Harley-Davidson 74. Plates for these feature a substance more similar to brake lining, a hard-faced material that comes from the makers of Raybestos. However, plates with the softer Armstrong material also are available to the 74 rider. It seems to be a matter of personal choice, probably influenced by the way the bike is ridden.

WET VS. DRY

Taylor stated a preference for dry clutches, indicating that plates run in oil tend to stick together too much. "The sticking problem is even worse after the plates become slicked up," he added. I asked about the heat factor in dry-versus-wet clutches and was told that heat was not an important consideration with the Barnett friction material. The only exception, according to Taylor, probably would be found in extreme cases involving intentional slipping or a combination of slipping and heavy loading, such as in quarter-mile drag racing.

CLUTCHES

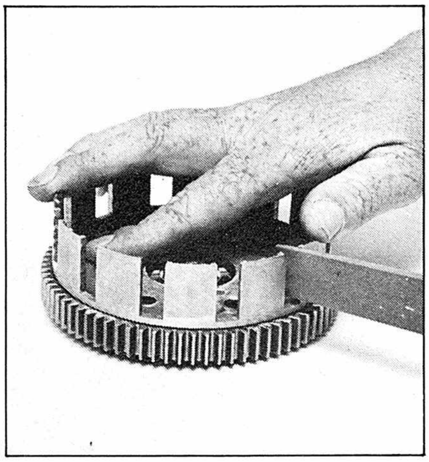
PLATE INSPECTION

Art takes over from science as we learn that there is no practical value to measuring the thickness of friction-lined driven plates. You can use the thickness method as a means of making a very general decision as to the remaining life of a clutch plate. However, it is much more important to learn to use your senses of sight, touch and smell when appraising the condition of a plate. The severely-burned friction segment will have, very simply, a scorched smell! It may very well look and feel slick and glazed. If extensive slipping has taken place, check both the driving and driven plates for warpage. Warped plates should always be replaced.

The next step is to take a look at those little tabs. You'll find them on the outer circumference of the driven plates and on the inner circumference of the drive plates. If possible, compare them to new plates so you can obtain an idea of what they're supposed to look like. If the wearing is not too severe, these tabs can be filed so that their edges are again parallel. Remember, however, that the now-reduced dimensions of these tabs is going to provide even more room for them to lash back and forth in the spline cuts, thus making a bad situation worse.

But what about the plates that still show an appreciable amount of thickness—with no warping and good tabs? They're a bit slicked up and that's about the worst of it. You have the option of salvaging these plates and saving yourself some money. Begin by thoroughly cleaning each surface. Follow the cleaning by roughing up the surface with a medium-grit paper or cloth, but remember you are just more or less etching the surfaces, either metal or composition, you're not necessarily grooving them. Heavy scoring with abrasive materials will only speed up wear as the plates come together and separate. "Just knock the glaze off," says Mike Taylor. But with this instruction he adds a caution: "Avoid having them sandblasted. If you feel you must sandblast them be very careful because they (the steel plates) can be warped." There scarcely seems to be a need for stating that plates with composition segments should definitely not be sandblasted!

Before I put the question of automatic transmission fluid to Taylor, I asked him about a preference for either steel or aluminum plates. There were some strong recommendations for aluminum. There's the obvious advantage of lighter weight. To that was added a statement that the T2075-T6 aluminum used by Barnett rids itself of heat more quickly and therefore is less apt to stretch and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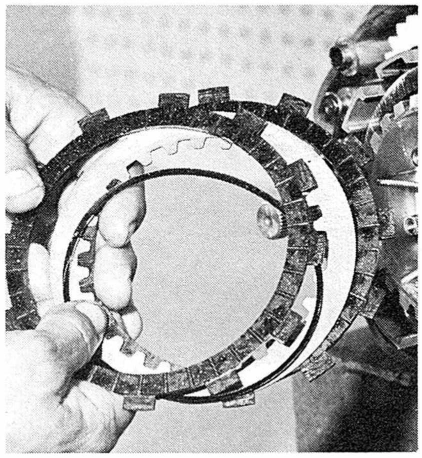
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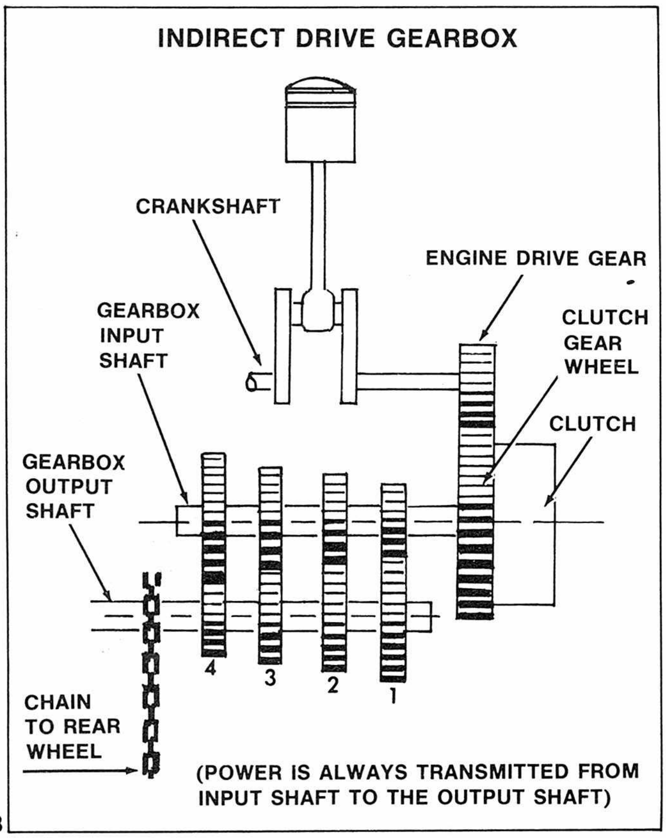

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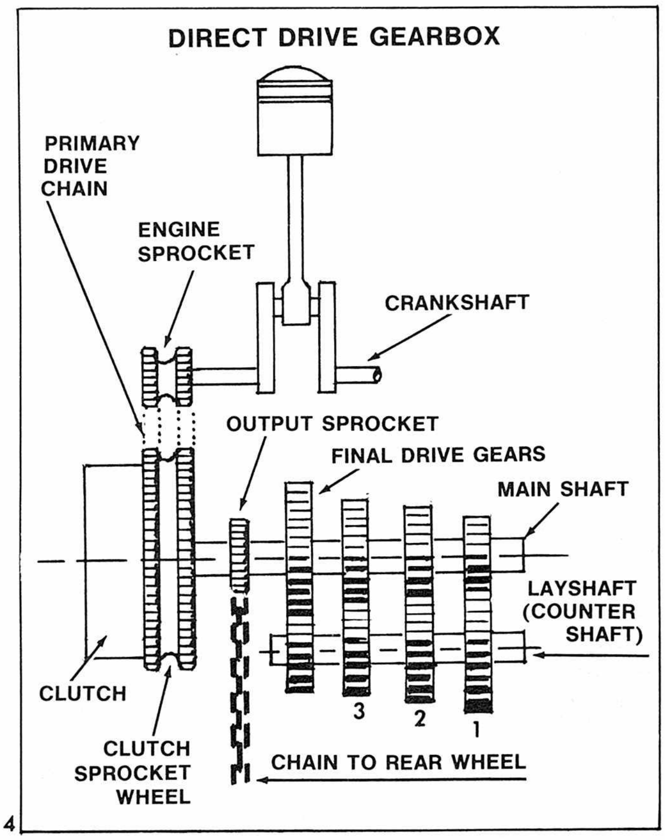

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warp. It's also somewhat harder than most steels commonly used for clutch plates and, when you think about that, you will see that the tabs will hold up longer. Beefing up the benefits of installing aluminum plates is the fact that they no longer cost more than those made of steel.

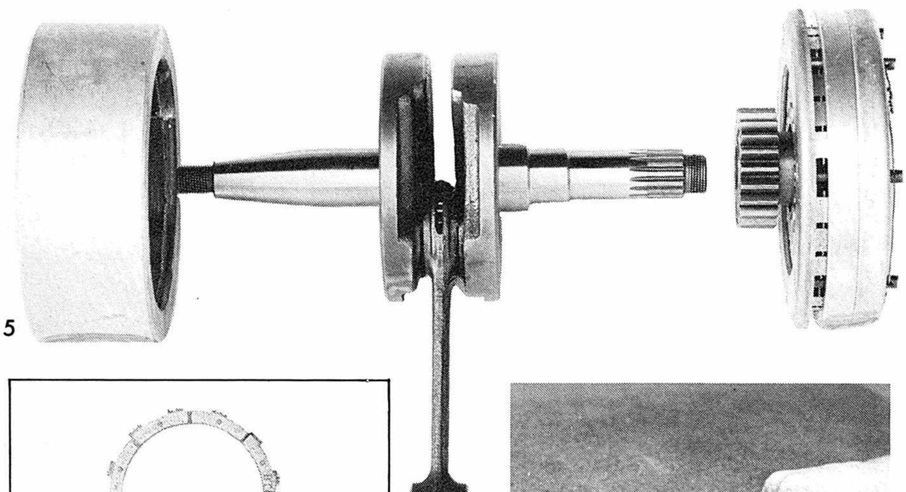
ATF, THEN AND NOW

Now, about ATF, is it or isn't it a good idea for use in bikes? Taylor indicated that a few years back it would melt the adhesive that held the friction segments on the metal. In that way it caused real trouble. In still another way it might not have been quite the thing for those earlier bikes with sleeve bushings in their innards. Now, however, with ball and roller bearings in use and a new adhesive that won't give up, ATF is all right. As far as use with Barnett plates, Taylor states emphatically, "We recommend it!" "In fact," he continued, "we sometimes have calls from riders who say, 'I just put in one of your clutches and it won't work.' " The upshot of these complaints is usually that the customer has used too heavy an oil and it is causing the plates to stick.

We'll come back to the subject of ATF in a few minutes. Right now, it's time to look at a couple of other aspects of Barnett plates as compared to the stock, factory variety. The Barnett plate is a product whose design and manufacture has been dedicated to durability and the ultimate minimization of that age-old bugaboo, slipping. The slightly softer friction material, special phosphate etching on all metal surfaces and greater contact area seem to accomplish the desired effect. Because of the increased clutching properties, Taylor indicated that heavy-duty clutch springs are not recommended with Barnett plates.

TRANSMISSION TALK

I still had slipping clutches on my mind as I began my conversation with Hodaka's Mike Hamilton. I wanted to learn something about Hodaka's ball-lock shifting system. Fortunately, I learned more than I had expected. Maybe it should first be realized that the Hodaka transmission has to be turning in order to shift. If the bike is standing still, it must be rocked back and forth to make the necessary gear changes. This is, to a limited extent, true of most transmissions. While most constant-mesh transmissions have the power transferred through the clutch, to a mainshaft, thence by gears that are moved back and forth by shifter forks, to corresponding gears on a countershaft, the Hodaka ball-lock has a series of 20 balls that are moved by the shifting linkage to bring about gear changes. The balls are thrust by a ball receiver so as to index into whichever gear is selected. The ball receiver is on a control shaft which moves inside a countershaft with 20 holes in it. On either side of the ball receiver you'll find a coil spring. These springs are designated, "Control shaft spring, left," and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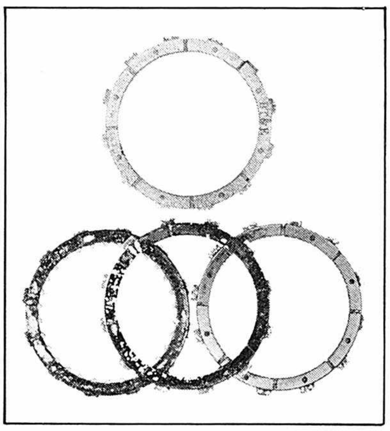
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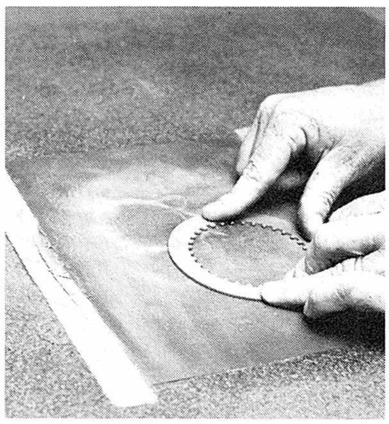
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1. Clutch housing gears can serrate. Filing should correct unless severe.

2. Rubber O-rings push oiled plates apart when stuck together from suction. Good idea to replace them if cracked.

3. Indirect drive transmission must transmit power from input to output shaft in all gears. Sprocket external.

4. Common with British is direct drive design. Minimal power loss in top gear. Sprocket between clutch and gears.

5. All Hodaka models have crankshaft-mounted clutch. Good for torque inertia but impedes high speed disengagement.

6. Barnett clutch at top arrests problem of plates 'welding' together.

7. De-glazing cork friction plates with emery on flat restores adhesion.

8. Burnt cork plate can be saved sometimes by de-glazing. Acetone clean first.

"Control shaft spring, right," so if you're assembling one of these units, be careful to install in the correct left-right order. Hamilton wanted Hodaka do-it-your-selfers to know the importance of paying careful attention to those two springs because they can tend to collapse. However, if the springs are at fault and shifter adjustment is not possible, you can remove them through the right side by taking off the right cover, then the primary gear and clutch. Nothing to this point will have offered much resistance, not till you come to where you have to remove that little snap ring. This is where you can spend a couple of hours pricking away with a pocket knife or an ice pick and probably wind up wounding yourself. The preferred alternative is Hodaka snap ring tool (#909524). The current price is $7.29—fairly heavy, but not when you think of the grief it can save you by turning a frustrating hour or two into a two- or three-second operation! Once the snap ring is out, you can pull out the shaft and get at the springs. They're probably inexpensive, so it sounds like a matter of automatic replacement rather than measuring, checking tension and all that. You might also want to check the ball receiver while you're in there, just to be sure everything's right.

SLIP A BIT—SAVE A LOT

We were on the matter of minimizing clutch slip with Barnett plates when Hamilton came forth with the revelation that the Hodaka plates are meant to slip, just a teensy bit, when gear changes are made. The idea is to take some of the shock off the gears. The same holds true when the bike comes to earth again after sailing some distance through the air. Now, anyone with a small, high-revving motorcycle can perk up and pay attention. Take a small screamer and let it take off the crest of a jump without shutting down the throttle. According to Hamilton, rpm's can climb very rapidly, say to 2500 . . . perhaps five times as high as a larger machine (like a 250). The result can be a substantially heavy shock to the gears in the transmission and rear chain. The calculated "give" in the Hodaka clutch works to spread these impulses over a longer period of time. While this is happening, the shock of sudden gear changes and rear wheel landings have been distributed over several gear teeth, instead of being soaked up by just one or two. Consider the proportions of that small bike transmission and remember it isn't the hairy piece of machinery you get with a Harley 74 or a Norton Commando!

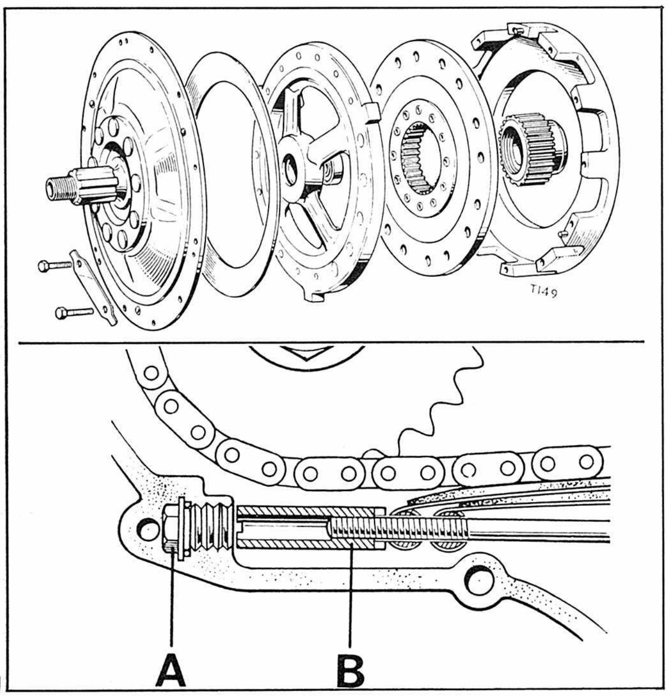
SHIFTY, EH?

We talked about getting information from the people who make the parts and those who install and repair them. Steve Kolseth seems to qualify in all three categories and had some commentary on shifters for the Sachs, DKW, Penton and the newly imported Monarch (all use the Sachs/DKW engine) motorcycles. This group's shifters, whether four- or six-speed, are of the same design. The idea is similar to the Hodaka, except that one spring is used, instead of two. Also, instead of balls, a long "T" bar engages the gears. Kolseth was not, however, specifically referring to Sachs shifters, which seem to have had some shimming problems (in one degree or another) for some time. He was talking about a replacement shifter set-up called the Koba Kit, which sells for just over $40.00 and can be put on in two or three hours by anyone with a moderate amount of mechanical ability. There is a claim for the elimination of all false neutrals along with other advantages.

As far as shimming with the Sachs setup is concerned, the advice was to "Start with the shift mechanism at the case and shim it on out from there. There are three or four different spots where you can put shims. With four or five different thicknesses available through dealers, a guy can get everything about perfect. The idea is getting everything as tight as possible without binding up."

A MULTITUDE OF SHIMS. . .

"A necessary evil" was about the most consistent comment that came in response to questions about shims. Bob Snow and Mark Rosendahl were two more knowledgeable people I talked to. In this instance, their qualifications included several years' ex-



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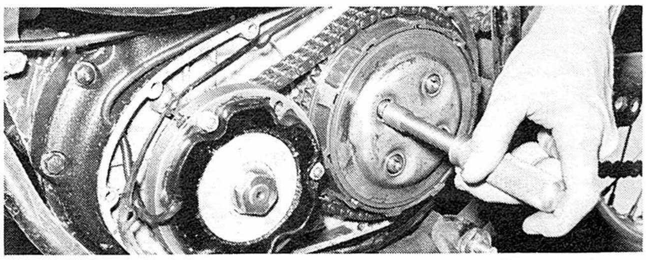

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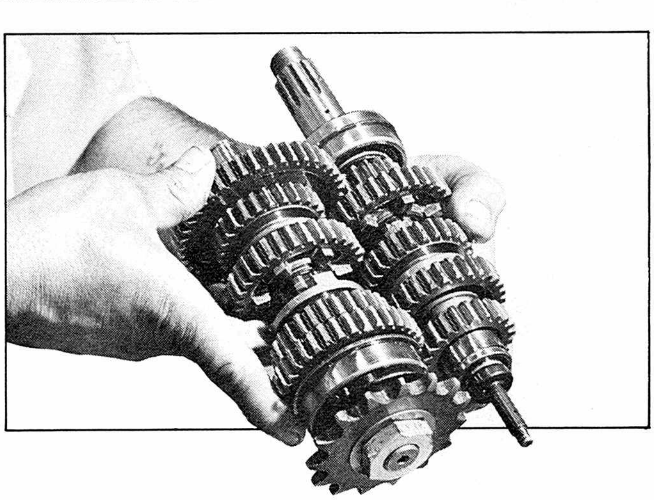

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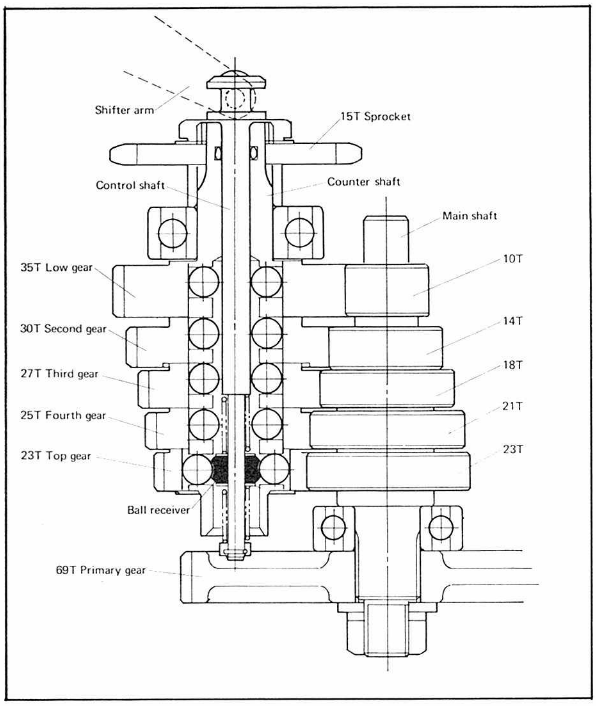

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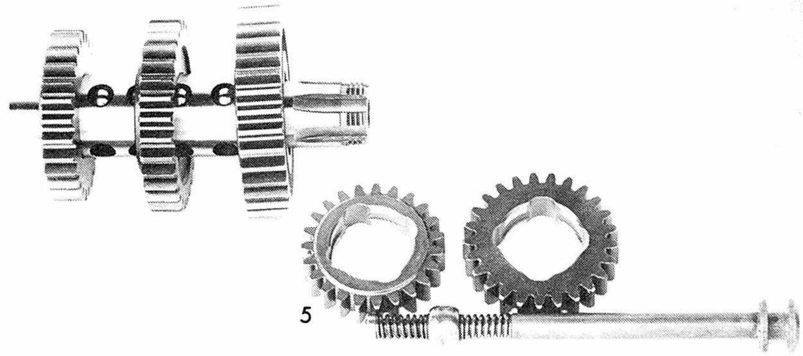
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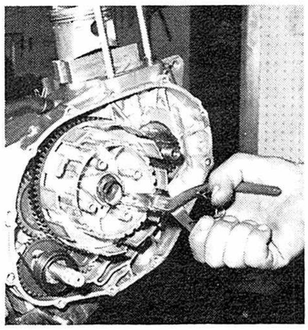
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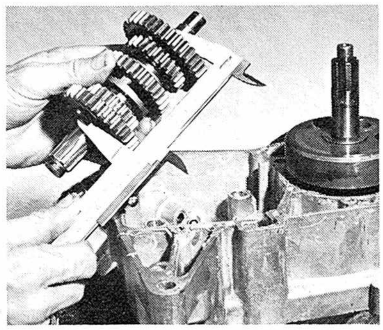
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1. Triumph Trident uses single plate dry clutch. Works well. Primary chain adjustment is screw; lifts follower.

2. Spring tension adjustment adjusts plate wobble. Spin with clutch in.

3. Indirect drive transmission has gears constantly meshing; Yamaha 350.

4. Unique ball-lock transmission of Hodaka's is simple. Top gear engaged.

5. Ball receiver pushrod runs inside drive shaft. Pushes balls out when moved laterally to lock gear on shaft.

6. Plan on need for circlip pliers when working on Japanese clutch and gearbox. Enormous Honda 250 single clutch will probably never fail.

7. Transmission end play should be kept around .015-inch. Measure assembled cluster on shaft. Then measure inside depth of case halves. Subtract gear length from case width.

perience in installing and repairing motorcycle clutch and transmission parts. Snow was quick to suggest that most clutch replacements are necessitated by an over-tight adjustment on the clutch pushrod. Somewhere, guys get the idea that the adjustment screw should be tight against the end of the pushrod. Snow didn't say that, I did! This happens to be one of the flukes I've seen all too often. The idea is to run that screw in till it just touches the end of the pushrod, then back it out a little and set the locknut. Be careful, because this is where the locknut can bind up on the screw just enough to carry it back in against the end of the rod, spoiling the adjustment. Note the position of the slot in the screw before you set the locknut. If possible, put a screwdriver through a box wrench and hold the screw in position as you secure the locknut.

As far as shimming techniques are concerned, both Snow and Rosendahl agreed that the first thing the home mechanic is likely to do is fail to get the original shims back in the way he took them out. Otherwise, it is a good idea to be sure that there isn't too much movement of the gears in a back-and-forth direction along the length of the shaft. You can figure a maximum allowable movement of .004- to .005-inch. The Yamaha 250 is one that was mentioned as occasionally having a jumping-out-of-gear problem which may be cured by proper shim spacing of transmission gears.

MORE ON ADJUSTMENT . . .

It seems that everyone who has ever worked with or written about transmission maintenance and repair agrees that the great majority of transmission problems can be traced directly back to incorrect clutch adjustment. Regardless of the cause, however, occasionally it becomes necessary to open up the gearbox for the replacement of parts. If such has been your fate, consider what you'll have to be looking for.

LET'S INSPECT THE FORKS

The bending of shifter forks is perhaps one of the most common ills, and knowing when they should be replaced is important. In the first place, it isn't a good idea to try to straighten a shifter fork and put it back in an otherwise good transmission. Once it's bent, and bent again to get it back to its original shape, it has been weakened and is therefore more liable to break and cause serious trouble. Check shifter forks for signs of discoloration from heat, chipping and pitting while you're about your diagnosis. A worn fork is also a source of trouble and should be replaced. Finally, be sure that the forks move freely on their shafts before you begin to follow reassembly instructions.

. . . AND GEARS

Gears, too, are subject to diagnostic inspection. Again, as with the forks, signs of unusual wear should be cause for replacement. Gears which work together should be replaced together. It isn't wise to replace a gear and not replace the one it works against. A mismatch is created that will cause the new gear to wear more rapidly, to say nothing of the noise and other difficulty that may result.

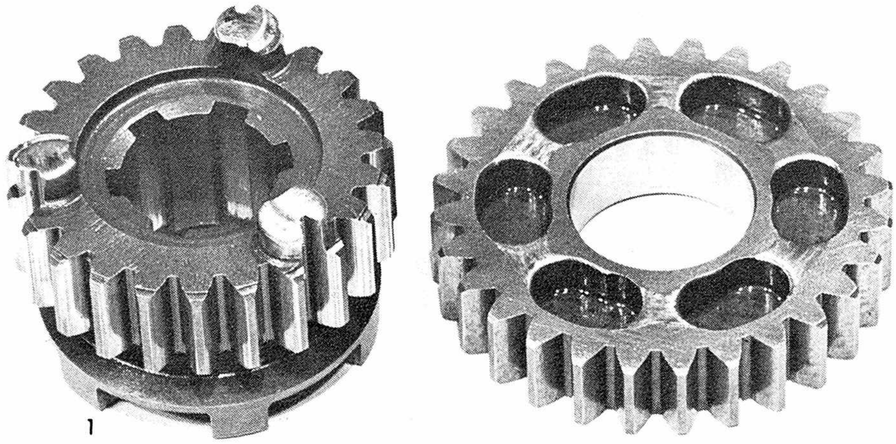
It happens that, not knowing simple shortcuts, the inexperienced will often make entirely too much work for himself. Take the Husqvarna, for example. I talked to Imperial Motor Sports, locally, and learned, for one thing, that it's a waste of time to look for an adjustment on the shifter mechanism: There isn't any! Also, according to Imperial, the workshop manual doesn't tell you that you can pull the

transmission out of a four- or five-speed bike without removing the clutch. It seems that the guys don't believe it can be done with the result that they never even try. There apparently is no detailed run-down on "how-to" . . . you just do it! Getting it back together was described as a sort of "safe-cracker" technique. "Just tap the cases together, and, as you do so, slightly rotate the clutch and it'll almost always line itself up and go in," I was told.

And take note of this, you Bultaco buffs. When you're putting the shifting mechanism back in a 250 five-speed, look for a circular plate, the one behind the pläte that's held in place by three screws. This circular object has a couple of notches for the spring-loaded triggers that take care of shifting. Now, you'll see a long arc and a short arc. Be sure the short arc is at four o'clock. On the 360 four-speed the short arc should be at 12 o'clock. The outside plate on the 360 should have the short arc at six o'clock. There is an outside plate on the 250 but, according to Bultaco, it'll only go on one way. There are reportedly three ways of putting some of these set-ups together, so the tip on position of these arcs is worth remembering.

Also from Bultaco, all five-speed parts books and workshop manuals have a drawing that shows the shifting fork on the right as upside-down. Remember that the fork on the right should have its longest arc on top, instead of on the bottom. So, don't follow the diagram—at least with respect to the position of this one shifter fork—if you want to be able to get into fifth gear! This is not necessarily a case of bearing down on the Bultaco manuals, I have seen it happen in many others. The reason may be traced back to the fact that the fellow who illustrated the parts wasn't entirely hip to the function of what he was drawing.

When adjusting the Bultaco's clutch springs, they say go in about three full turns, then adjust to where everything runs true. Also, the new Bultaco plates are said to be capable of withstanding abuse without swelling. The plates, alternately steel and cast iron at one time, are now all-steel. This would indicate the absence of any composition friction segments on the driven plates.



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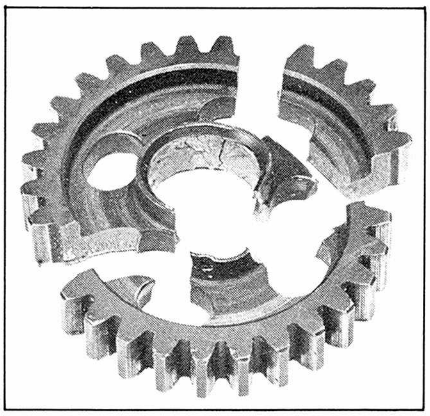

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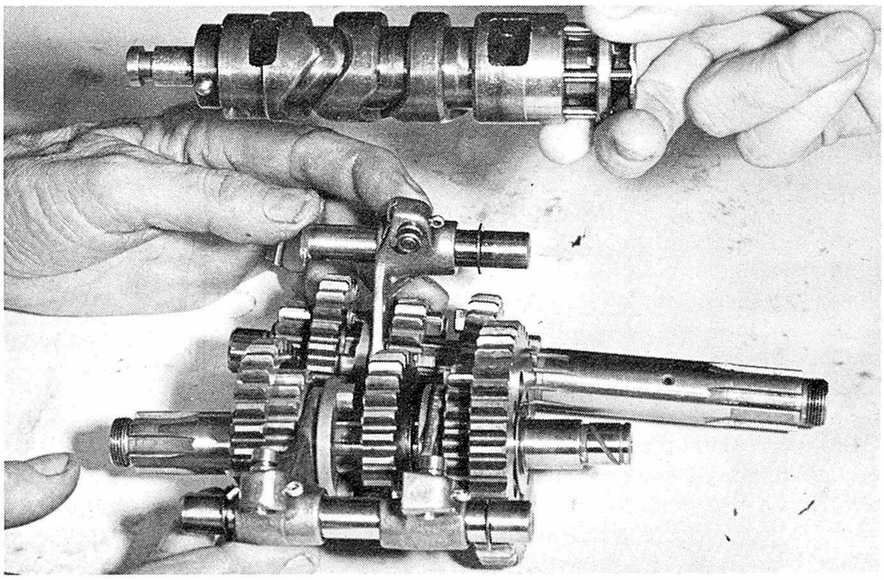
TIP ON TRIDENTS AND OTHERS

There is one thing about adjustment of the Triumph Trident clutch that is deserving of momentary attention. The workshop manual, in referring to internal clutch operating mechanism adjustment states: "Very little movement is required in the clutch pullrod to disengage the friction plate, so there must be a clearance of not less than .005-inch between the rear face of the large adjuster nut and the ball bearing in the actuating plate." The foregoing statement is absolutely correct. You take a fagot of thickness gages, pull out the one marked, ".005," and start adjusting. What the book doesn't tell you is that there will inevitably be some tiny amount of space between the threads on the end of the pullrod and the threads in the small adjustment nut when you have loosened it to make the adjustment, and there is no force on the threads



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1. Proper shift adjustment and religious use of clutch arrests 'rounding' of male and female gear dogs.

2. Too much gusto with the throttle, popping the clutch and old, dirty oil let this gear seize on shaft, explode.

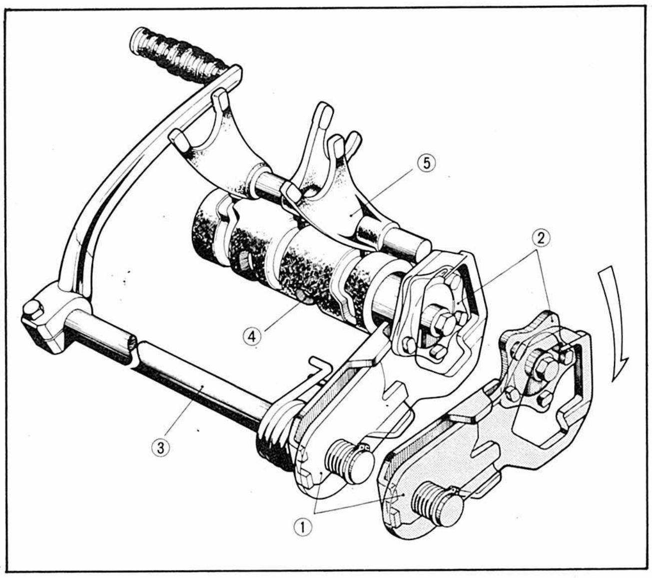
3. Popular with Japanese is shift cam drum setup for five and six speeders.

4. Honda uses this novel shift plate shifter on their cam drum to eliminate gear jumping in their 100-125 singles.

5. Shift forks must be straight, parallel. Fork on left is bent, must be replaced. Impossible to straighten.

6. Kawasaki uses the more popular cam drum pinned on one end. As shift lever is moved, change arm ratchets drum to move gears laterally.

7. Fork is burnt and worn excessively from improper adjustment. Can also be caused from holding lever up, down.



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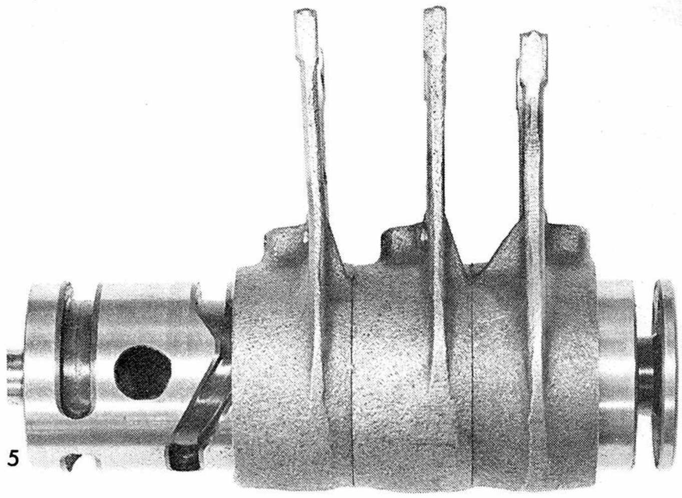

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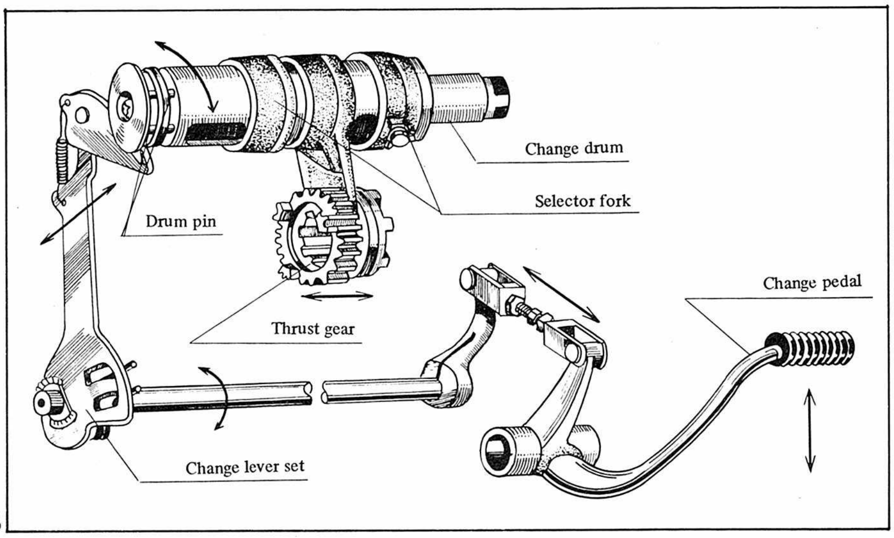

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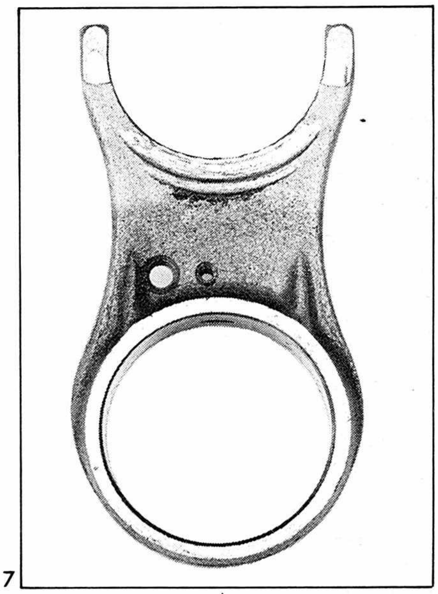

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in either direction. This slack may amount to no more than a couple of thousandths, but this adjustment is somewhat critical if you want satisfactory clutch operation. What happens if you set the large adjuster nut for the desired .005-inch and tighten the locknut? The slack is absorbed by tightening and you've lost your adjustment. Learn to allow for this discrepancy before you set the locknut and you'll save yourself a lot of grief. The idea of slack in adjustment threads can be applied to other motorcycles and other situations, too. Tappet adjustment, to mention one.

OIL'S WELL THAT ENDS UP ON THE PAVEMENT

Little attention is devoted to primary chain case covers or engine and transmission casings in the average written word on the maintenance and repair of motorcycles. That may account for the fact that so much attention is drawn to those inevitable puddles of oil found under transmissions and primary chain cases on many bikes. A drop or two after a run of some distance is not necessarily cause for concern. However, despite the hardened belief of many individuals, the propensity to puddle is not a calculated engineering feature of certain makes. There is no mystique involved. If everything is right in the assembly, and condition of cases, gaskets and seals is good, there should be nothing more than that drop or two I mentioned.

You say you've replaced the seals, made sure nothing is warped, and that all surfaces are getting maximum contact over good gaskets, and all the screws are tightened to the point of stripping, and she still leaks? It could be you've got an invisible crack somewhere. It can happen that a crack of this sort will escape attention at the factory with the result that even a brand new machine will plague its owner with seemingly unfixable oil leaks. The chances for invisible cracks in aluminum casings will increase in direct proportion to the age of the bike and the kind of treatment it has endured.

There are at least two relatively inexpensive solutions to the dilemma of invisible cracking. If you were working with a ferrous metal, magnafluxing would be the answer. Aluminum, being non-magnetic, calls for other tactics. One involves a three-step process with the use of something known commercially as Met-L-Check. A red dye is first spread over the entire surface of the aluminum. It dries in about five minutes and is wiped off with a remover, also included in the kit. Finally, the surface is sprayed with a liquid chemical which causes it to appear a pinkish-white. If a crack is present a certain amount of the dye will have worked its way in and will thus have escaped the wiping done in step two. When the last treatment of chemical was administered, in step

three, it caused the dye to react and come to the surface. The result is a distinct red line along the entire length of that previously invisible crack. Another die-check method is available through the Mackay people. I have not personally tried this method, but I have known others who did, and successfully. The Mackay liquid (maybe someone else also makes a similar product . . .) is mixed with the oil and will color a crack purple, I believe—so it can be located and repaired. This latter method can be used while the bike is in operation.

ATF . . . RAH! RAH! RAH!

It was back to the question of ATF in bikes as I began my interview with Lee Burch, long-time Harley-Davidson dealer in Whittier, California. His recommendation of ATF, at least in the Milwaukee product, was enthusiastic and without qualification. Burch was specific, though: "Ford ATF is what we use. It is especially good in transmissions in brand new bikes during the run-in period. It lets machine-chips from new surfaces go right to the bottom of the case where it won't be caught up in there among the gears and do any harm. Anything in the gearbox is liable to be carried up by some heavier oil to where it'll cause extra wear."

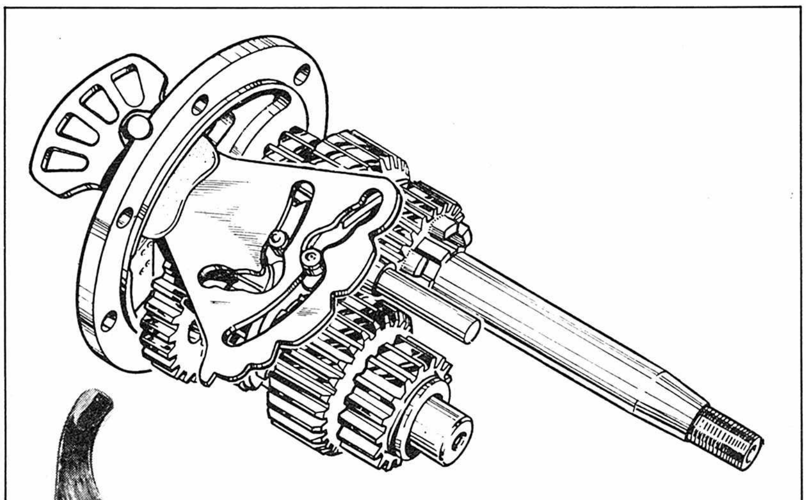
TRANNY, WHAT BIG TEETH YOU HAVE!

There was a tip, too. It concerns a lot of people who take the speedo cable off their Harleys. The drive end is removed from the transmission, right in a place where it is wide open to all manner of grit and other foreign matter. The drive mechanism is still turning, even though the cable has been removed. If dirt causes it to lock up, the worm can hop up amongst the gears and the misery of having the fleas of a thousand camels take up residence in your beard will be condensed into a few danger-laden seconds!

ATF CAUTION

I thought more about ATF in transmissions and clutches and wondered about using something that light in a bike that had a system of sharing oil between, say, the primary chain case and the engine. The late Triumphs, among others, are included in this category, so I got in touch with Bob Ellison of Triumph's West Coast operation and asked for a statement. Although there isn't a gorging spate of oil passage between the late Triumph's lower end and the chain case, putting anything as light as ATF in the chain case is not recommended. Then what about the recommendation for one weight in the engine and another in the primary. The answer came to me this way: "Use a multiple-viscosity oil. Something like one of the better grade 20W-50s will do."

Then what about these rider manuals that recommend 90 gear lube, or 80, and then the guy in the bike shop will tell you to substitute 40- or 50-weight oil? This question prompted my contact with Rob Lancaster at Torco Oil Company. It isn't as confusing when you hear it from someone who knows what he's talking about. Lancaster, whose father, Bob, developed many of the Torco products now in circulation, explained that a different set of weight numbers had been assigned to the gear lubes. That's why you'll find that 80 gear lube will have the approximate viscosity of 30-weight motor oil. Likewise, 90 gear lube might come out about like 50-weight motor oil. But wait . . . they're still not the same. Temperature, it seems, will tend to



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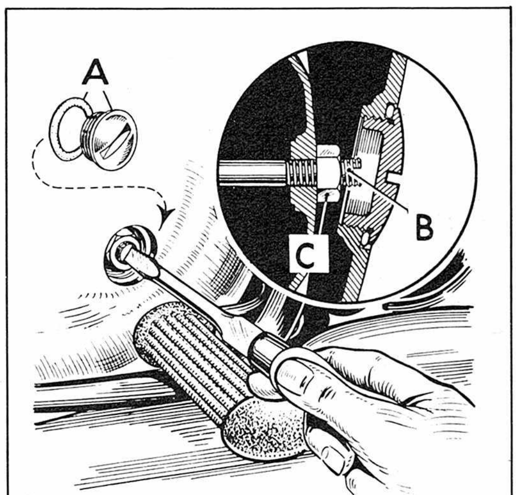

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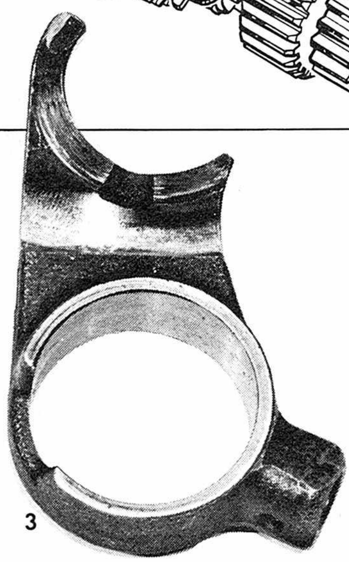

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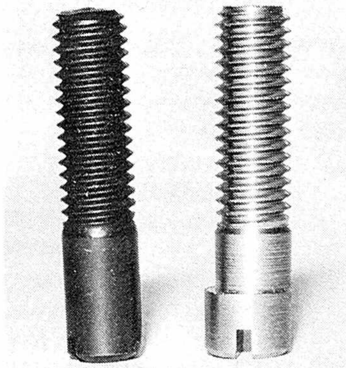

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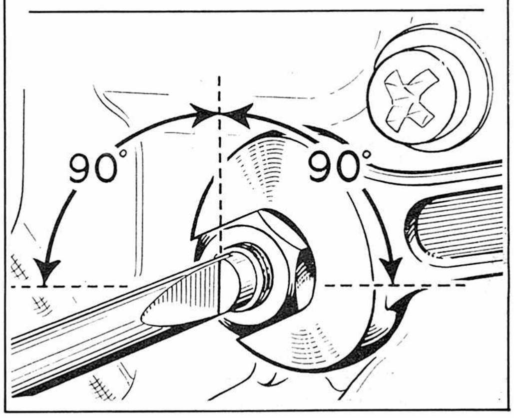

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make more difference in the fluidity of gear lubes, perhaps because the makers employ more cross-blending to achieve some specific viscosity. On the other hand, motor oils have more "built-in" cross-fluidity. Some of this is purely rote on my part, but I believe the explanation clears up a lot of misunderstanding about viscosity scales. Stick to gear lube if recommended.

A FINAL THOUGHT ON ATF

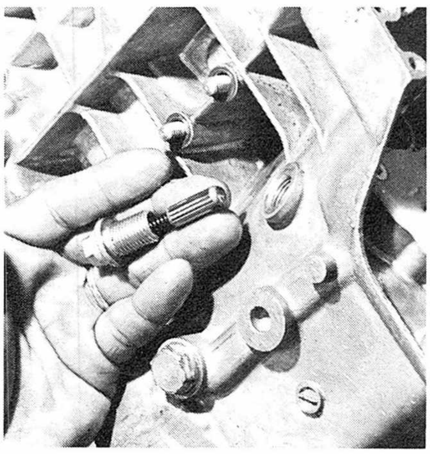
"ATF is possessed of some good anti-friction characteristics which should make it recommendable for clutches," says Lancaster. This more or less came as a culmination of remarks that I'd solicited on the stuff. It is generally a good idea for use in the clutch. If the clutch housing also includes your primary chain it shouldn't make any difference, and the same goes for any ball or roller bearings present in the area, although sleeve bushings just might be another proposition. As far as using it in transmissions is concerned, there was some question in the mind of Lancaster about ATF's load-carrying abilities when you consider the sheer pressures exerted between gear teeth. If in doubt about using ATF, use the recommended lube or gear oil until you can qualify its use with an experienced mechanic.

GEAR CHAIN . . . NEW TO BIKES?

Honda used a gear chain on their land speed record attempt bike, probably as much to indicate their faith in it as it was for its reliability. Gear chain is a series of seven or so little plates pinned together in segments to take the place of the links you have come to be familiar with in regular roller-type chains. Gear chain presents a smooth surface from the outside with a gear-tooth inner surface. Then, instead of working between two sprockets, it works between two gears. This is the set-up reportedly used on the new Honda 350 and 500 four-cylinder bikes to transmit power between the engine's crankshaft and the clutch. Most of the Honda people I talked to said it was too soon to know whether gear chain as a primary drive component was going to work out or not. The reason, generally, was that there were not any machines out of their dealerships with really high mileage on gear chain primaries. The four-cylinder 750, incidentally, still uses regular roller-type primary drive. But, getting back to the gear chain, you probably know it has been used extensively on automobile engines for years as timing chain.

We've mentioned roller chain as primary drive and we'll be back to it shortly for a look at some of the things that apply to its adjustment and wear. Right now let's discuss the type of primary drive system that's most likely to be found on smaller machines. This is the gear system where one gear works directly off the end of the crankshaft to drive a corresponding set of teeth on the outer circumference of the clutch housing wheel. These are of two types, helical and straight-cut. Some say that the helical, or angle-cut type, is quieter and smoother for pure pleasure riding. However, when you're after that last available iota of power, the straight-cut variety is definitely preferable. The reason is due to loss of power that stems from whatever minute amount of side thrust loading friction might take place as the slanted teeth in the helicals match up. This, of course, would not be present in straight-cut teeth.

As far as checking for damage or wear on primary gears is concerned, it might be thought of in much the same manner as regular transmission gears. The roller chain primary drive is likely to give a lot more trouble than gears, but permit easier ratio change. For example, not many riders are likely to blame a shaky ride on a worn-out or loose primary chain—no more than they'd blame rough shifting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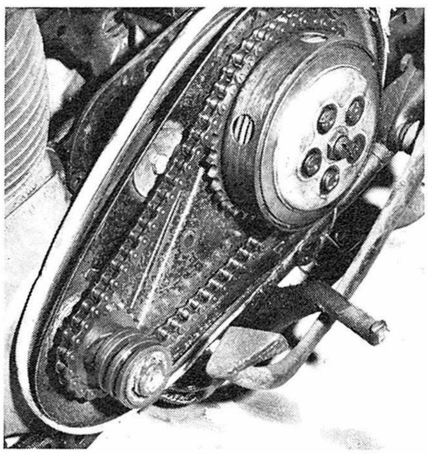
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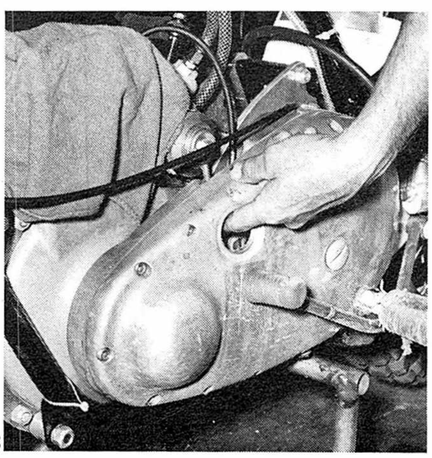
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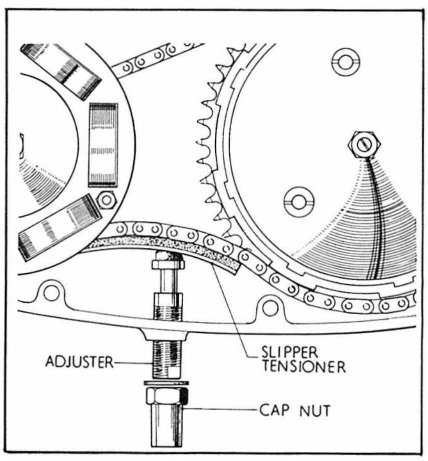

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1. Europeans, especially British, use simpler, more trouble free shift plate. Cammed grooves move forks, gears.

2. Also simpler is BSA clutch pushrod adjustment. Tighten, back off ¼ turn.

3. Top of shift fork is deep blue in color from burn after being bent.

4. Cammed eccentric screws are used to move and adjust shift linkage. Turning screw moves linkage up, down.

5. Locking nut holds eccentric screw in place. LocTite recommended.

6. Spring loaded detent rests against serrated cam drum or plate to firmly position it in gear selected, neutral.

7. Some torquer type engines use coil spring shock absorber. Allows sprocket to spin under sudden shock, saves gears.

8. Engines with primary chain drive need regular adjustment. Check play.

9. BSA uses adjustable slipper tensioner to take up chain slop. Older designs require moving gearbox back.

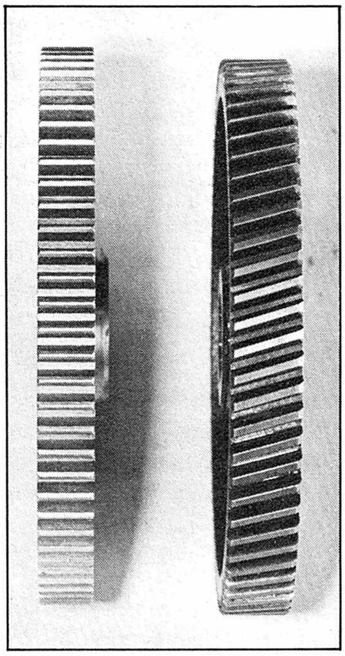
CLUTCHES

on an improperly adjusted primary chain.

Nearly every chain, primary or final drive (new or used) is going to have something of a "tight spot." As long as it isn't too pronounced this isn't going to hurt anything. However, if there is too much difference in the adjustment you can achieve on one section of a chain when compared to another, it is time for a new chain. The idea with any chain is to find where it is tightest before you make the adjustment and set it at that point. As you can readily see, setting the prescribed chain slack on the loose spot would create a dangerously uneven situation when the tight section came around. I have seen entire transmission housings on non-unit motorcycles snapped in twain like a fortune cookie by the type of mistake just outlined.

DON'T KICK IT, STROKE IT!

You may have guessed that the theme of much of what I have written thus far has been devised to keep you from having to open up your clutch or transmission in the first place. Like I said at the outset . . . let's attack this thing from the outside! Maybe "attack" isn't the right word. Neither is "kick!" Kick . . . you see it everywhere: kickstarter, kickstart mechanism, kick-crank, kick it! Kick is quite possibly the most damaging misnomer associated with motorcycle operation. The fan-gear and ratchet-and-pawl components in most bikes are pretty sturdy, but nothing of mere steel could possibly stand up under the brutal punishment to which it is subjected by a lot of riders. I have seen pawls broken, fan-gear teeth knocked off and transmission housings cracked—to say nothing of broken crank arms and pedals—by people who launch themselves skyward, then come down, muddy boots and all, with kill-vengeance on the starter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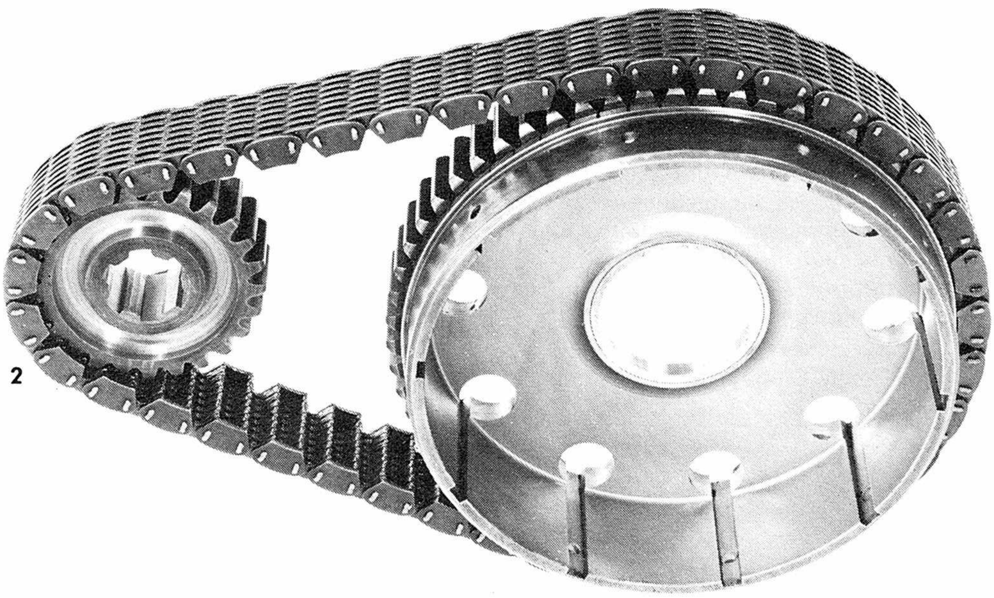
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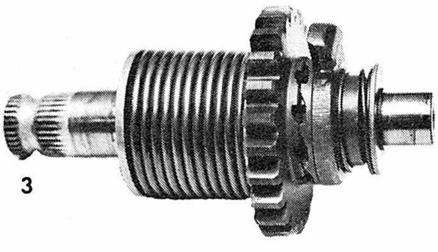
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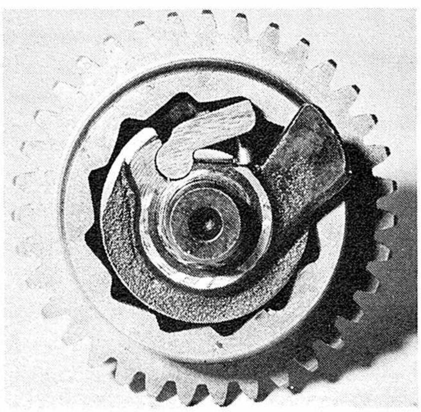
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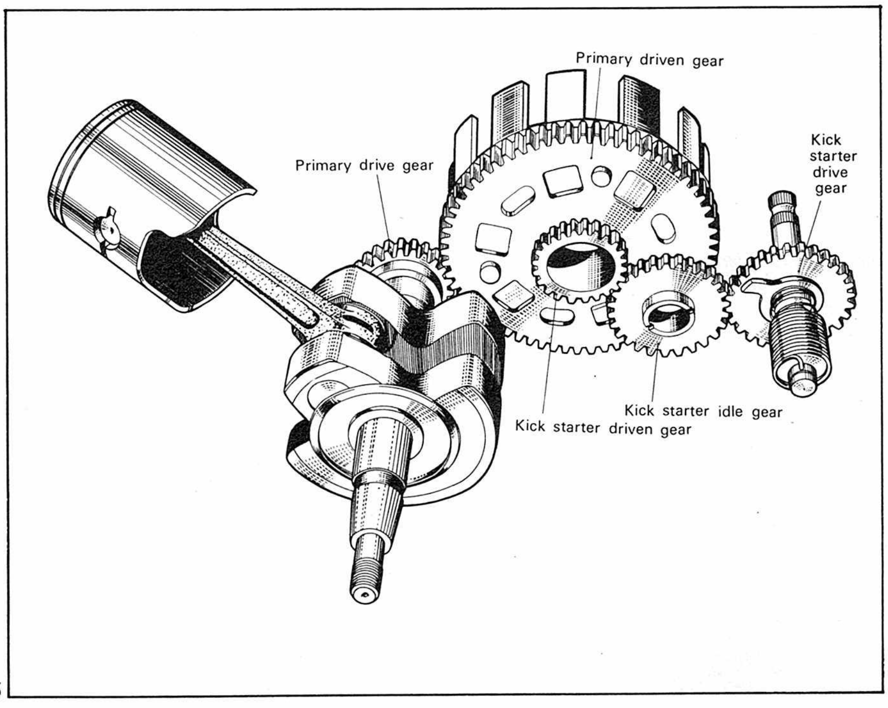

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mechanisms of their motorcycles. This is the unfailing sign of a rank amateur. You'll see the experienced rider put just enough weight on that crank pedal to assure correct engagement of the parts inside, then shift his weight over the pedal and come down with a smooth, even stroke. There's a lot less exertion involved and a lot more satisfaction in the long run.

I haven't been able to give you too many specifics. Clutches alone could easily absorb book-length attention, to say nothing of how little can actually be told of the entire power transmission train within the confines of just a single chapter. Instead, my effort has been to help you expand your concept of the things we've discussed and, in addition, emphasize the importance of being careful and using workshop manuals to the best advantage. At the same time I may have over-conveyed the idea that there is a delicacy about motorcycles, particularly primary chains and clutches. If this has been the case, be reminded of the 500cc. J.A. Prestwich and Jawa Class "A" Speedway machines. The primary chain and clutch on these bikes is operated in what you might call an open-air "sand-bath." The only oil the chains ever feel may result from an occasional squirt administered by a tuner between races. On relatively short American speedway courses these exposed components bear the brunt of nearly every conceivable abuse. Clutch bearings may benefit from nothing more than a carefree smear of Vaseline and, at that, only when they're periodically disassembled for cleaning. Otherwise, getting stuffed with sand or decomposed granite to a point of becoming wholly inoperable usually will call for no more than a few sharp raps with a rawhide mallet or a handy two-by-four. Clutches on Class "A" bikes might go a bit further, but you could doubtless figure a primary chain would be worth no more than a total of fifty miles of accumulated circle burning. You've got a lot more going for you if you'll observe the right maintenance and repair procedure.

1. Gear driven primary either straight cut or helical. Straight has less friction, more noise. Helical quieter.

2. Morse Hyvo drive becoming popular with high-hp engines. Quiet, strong.

3. Spring loaded ratchet kick start needs inspection for worn serrations.

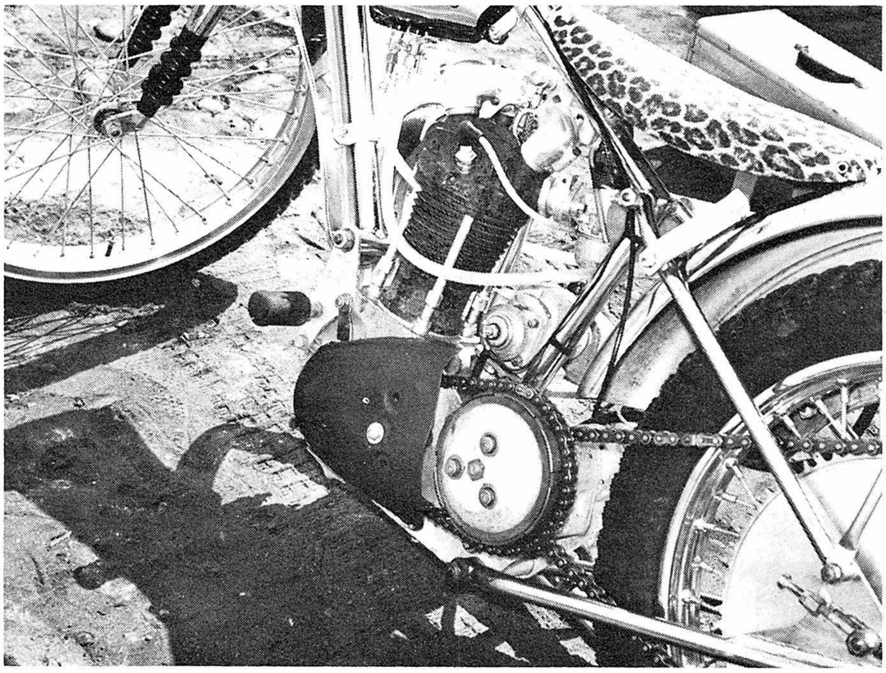
4. Kick pawl assembly also simple, but more sensitive. Serrations, pawl wear.

5. Typical kick start drive system goes through starter, idle gear, clutch to primary drive. Shown is Suzuki 400.

6. Speedway bike has external drive and clutch. Sand-bath clutch and chain undergoes severest of punishment.

7. Tachometer drive usually runs from worm gear off gearbox. Care must be taken to install perfectly straight and aligned. Slight cock destroys gears.

8. Kawasaki 350 road racer has special external dry clutch. Multi-plate clutch has less friction drag than internal oil bathed assembly.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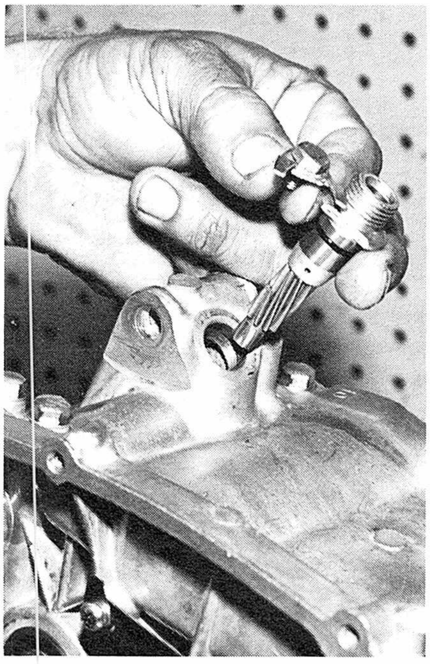
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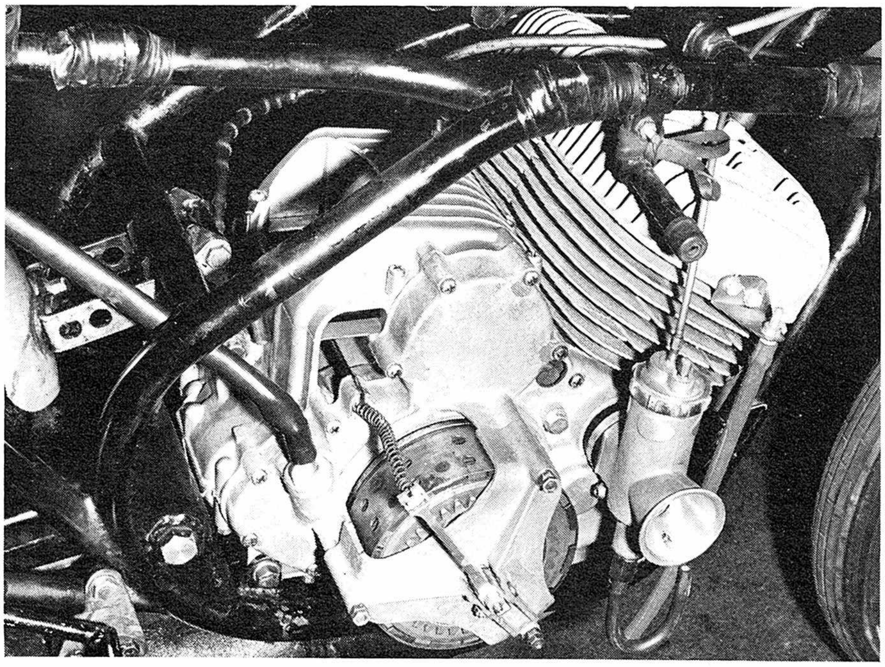
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THE FINAL LINK

With a little knowledge and attention, you can assure many thousands of miles of service from your chain.

BY DALE BOLLER

Although chains are rarely repaired or rebuilt, a good motorcycle repair manual must establish certain truths about these strings of steel which are a common failure in all types of riding. If a mechanic's goal is to ensure the reliable running of motorcycles, he must understand thoroughly these critical driveline components and know exactly how to keep them operable and efficient. No other system within a motorcycle receives the misuse and abuse of the chain systems (primary, cam and drive), so the mechanic must be able to spot improper applications or neglect, then correct the former, communicate to the machine's owner the dangers of the latter and finally explain to him the dos and don'ts of exact maintenance procedures. Study it carefully.

Chains are used in motorcycles where power transmission by gear or shaft is too expensive or technically infeasible. The choice is hardly a compromise, however, since a well-lubricated roller chain provides positive, non-slip drive at an efficiency of 98 percent. The positive mesh between rollers and sprocket teeth minimizes bearing loads on sprocket shafts since the chain does not depend on tension to provide friction drive as is necessary with a belt and pulley. There is also no side thrust.

Other benefits make the choice a wise one: A single chain can drive several different shafts, such as both cams in a 450, or the myriad of shafts within the timing case of the old 750 Royal Enfields. Chain installation is easy and the drive ratio can be altered by changing one or both sprockets. If adequately lubricated, chains don't deteriorate with age or exposure to the elements as rubber belts do. Roller chains are relatively cheap, compact, light and reliable. Due to standards set by the Association of Roller and Silent Chain Manufacturers and by the American National Standards Institute (ANSI), they are interchangeable among brands except on certain Iron Curtain bikes such as Jawa, CZ and MZ. A properly designed and maintained chain drive has slow, predictable wear and a long useful life—on the order of 15,000 hours of operation or 500,000 miles of riding! These figures are never reached in practice because motorcycle designers choose the smallest chain which will work at all in order to keep the drive as light, cheap and compact as possible. And of course in motorcycle applications ideal operating conditions are impossible to achieve.

There are two kinds of links in a chain, pin links and roller links. *Pin links* consist of two solid pins press-fitted into *sideplates,* or linkplates. These are the wider links. A *master link* is a removable pin link. The pins ride inside bushings which are part of the roller links.

Roller links are more complicated. A tubular bushing is press-fitted in each end of the sideplates. These bushings are usually curl-formed from flat stock and individual manufacturers have their own tricks for making and assembling them. For example, the bushing seam may be oriented toward the middle of the link so tension acts opposite the seam, or the ends of the bushings may be acid-etched to give better bite to the press-fit. The bushing seam on Diamond brand chain has a cutaway shaped like a diamond to act as a reservoir for lubricant. Fitting loosely over the bushing is a tubular *roller*. This is what contacts the sprocket teeth. Though the roller is free to rotate on the bushing, this is not its primary job. The main task of the roller is to absorb the impact as the chain and sprocket engage. Some chains, in small sizes, don't have rollers and the bushings run directly on the sprockets. These are called "rollerless" chains.

All chains are classified by size in terms of their *pitch*, which is simply the center-to-center distance between a pair of pins or bushings. Common drive-chain sizes are 3/8; 1/2-or 5/8-inch pitch by some varying width—classified by the width of the roller—usually in the area of 1/4, 3/8, 5/16 or 1/2. Most Triumphs use a 5/8 x 3/8 chain, and the Honda Four uses a wider 5/8 x 1/2 chain. Each link (roller link, pin link, master link) is one pitch long and thus the number of pitches always equals the number of links. This number is traditionally specified with the chain closed in a loop, i.e., including a master link. When you ask for a chain with 102 links, you'll receive a length 101 pitches long, plus a master link.

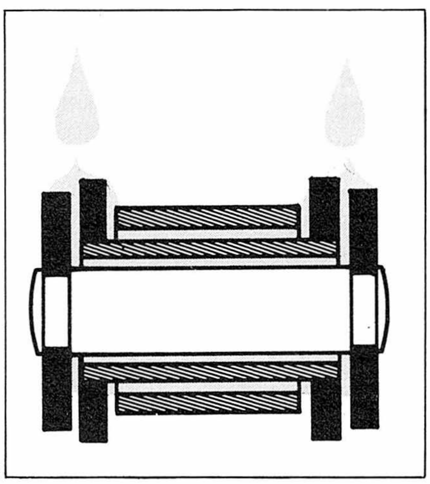
Though motorcycle people almost always refer to chains by their pitch and roller width, as 1/2 x 1/4 or 5/8 x 3/8.

1

Sometimes motorcycle designers want chain of standard size, but a little stronger; or the same size, but a little cheaper. Enter the special, or non-standard chains with non-standard numbering—No. 520, No. 530 or the popular Whitney No. 625, which is a high performance 5/8-inch pitch used by many 750 Honda Four owners. Whatever the number on a special chain, be sure the pitch and roller width is equivalent to that on the chain you are replacing.

Because the ANSI standards go back as far as 1913, they have penetrated throughout most of the world. There is a true metric standard, used on some European bikes (Jawa, CZ, Maico) that have different width and diameter rollers in standard pitch lengths and therefore cannot be interchanged with ANSI chain. New sprockets will be required to fit standard chain, so at the time you buy such a bike it would be a good idea to buy a set of replacement chains...a primary and two or three rear chains.

The accompanying table of chain proportions gives the principle dimensions of No. 35, No. 40 and No. 50 standard chains, the sizes most used on motorcycles. Roller diameter, linkplate thickness and other measurements are all certain proportions of pitch "P". Thus the roller diameter is 5/8's of the pitch, within a specified tolerance. The minimum-ultimate-tensile-strength,



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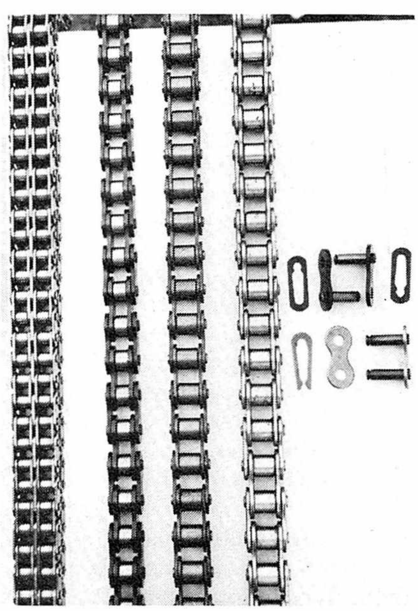
1. These small plates, links and rollers of steel must transmit all the power and work load of motorcycles from five to 200 horsepower. Full Bore's chain uses unique master links.

2. The secret to long chain life is getting lubricant where it's needed most. High friction and wear points are between link plates and the roller-to-pin surfaces. As shown here a small drop of lubricant in the right place will keep friction to a minimum. Quantity of lubricant is second to application method.

3. Chains are used to drive the gearbox, camshafts, timing systems as well as rear wheel power train. Thus the single, duplex, triplex and even the dual plate master link.

DRIVE SYSTEMS

Sprockets should have at least 15 teeth. This lower limit is set by "chordal action," or changes in link speeds while going to and from the sprocket. This phenomenon becomes increasingly severe when there are fewer than 17 teeth. Chordal action occurs thusly: The effective shape of a sprocket is actually a polygon; a six-tooth sprocket would be a hexagon, an eight-tooth sprocket an octagon, etc. A straight line between the pins of a link setting in two troughs of a sprocket represents one side of the sprocket's overall polygon shape. The center of this line, and therefore the center of the link, is minutely closer to the center of the sprocket than the two ends of the link. As the chain goes around the sprocket, the middle of each link has a different, slower speed than the two ends of the link, which are further from the center of rotation than the middle is, and therefore travel at a faster speed in order to cover a longer distance in the same time. On the other hand, all parts of a link have the same velocity when it is moving in a straight line between sprockets. This means that a sharp change in velocity and direction is required as each link engages a sprocket—which translates into a sharp impact of chain roller on sprocket teeth and certain wear producing pressure and bearing changes between pin, bushing and It causes a high-frequency up-and-down vibration of the links and, most important, it means that each roller experiences a sharp impact as it engages, and again as it leaves, the sprockets.



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The larger the sprocket, the closer is the approximation to a circle and the less is the effect of chordal action since there are more sides (link pitches) to the polygon and thus less variance in distance of the side's length from the center of the sprocket. Directional changes are also more gradual on a larger sprocket. On many motorcycles the output sprocket is too small, causing excessive chordal action and abnormally short chain life. Expect trouble when you see 15 or fewer teeth, unfortunately a common occurence on too many countershaft sprockets. Camshaft drives are another area where the designer may have tried too hard to save space by using small sprockets. Primary drives are usually OK. Whenever you lower a gear ratio, do it by fitting a larger sprocket on the rear, not a smaller one on the countershaft.

Sprockets should have no more than 70 teeth. Since gradual changes in pitch due to wear accumulate as rollers contact increasing numbers of teeth, large sprockets are therefore more sensitive to chain wear. Big sprockets don't cause extra wear, like small ones do, they're just less tolerant of existing wear by an amount given in the section on why chains fail.

Chain wrap is the amount of angle around a sprocket for which the chain and sprocket are engaged. Wrap should be at least 120 degrees, which is 1/3 of the way around the sprocket; otherwise too few teeth are carrying the load. This becomes a problem for high gear ratios and multiple-sprocket single-chain arrangements. Equal size sprockets always give 180 degree wrap, and the wrap will be over 120 degrees if the gear ratio is less than 3.5:1. Chain wrap is adequate on normal motorcycle drives.

Shaft centers are correctly spaced when the distance is between 30 and 50 pitches of chain. When the center-to-center distance

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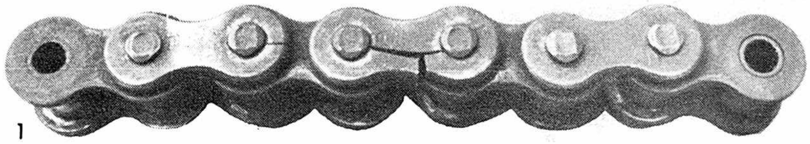

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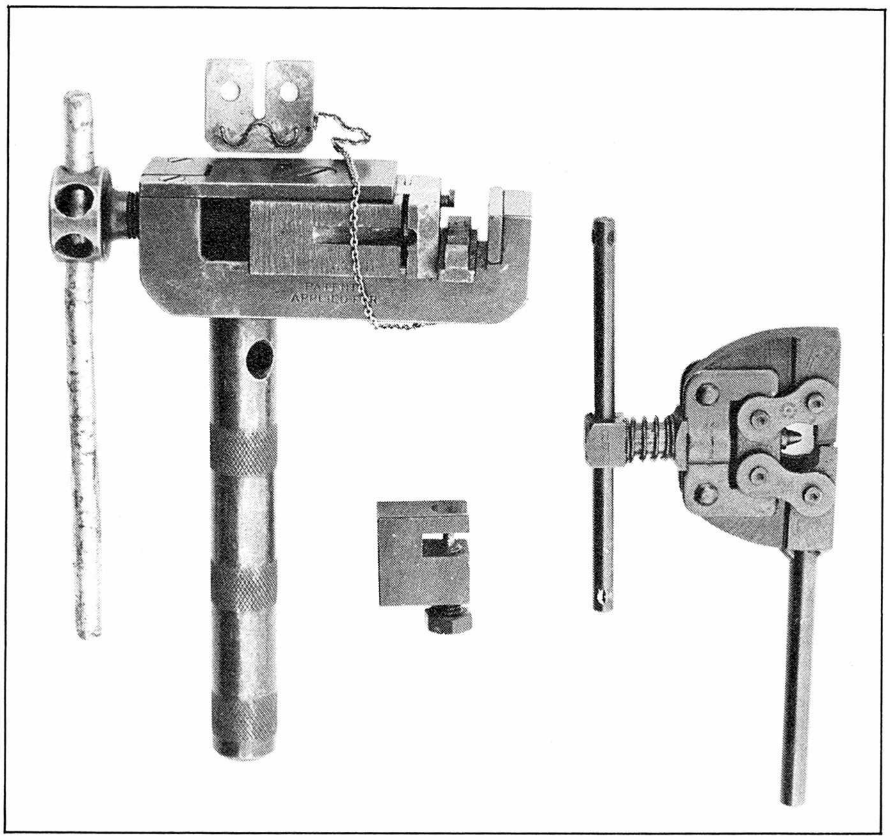

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between the output sprocket and the rear wheel sprocket is 25 inches and a 5/8-inch pitch chain is used, the spacing is 25 ÷ 5/8 = 40 pitches, which is good. Primary drives are often shorter, but not unreasonably so. In fact, spacings around 20 pitches are desirable for pulsating loads like the output of an engine. Very long chains will surge and vibrate, giving a rough drive and shortened chain life.

A *reduction ratio* of 7:1 is the safe upper limit for chain drives. In contrast, a worm gear can give 50:1 reduction. This is obviously a limitation for some applications, but not for motorcycles since the needed ratios are no more than 5:1 and are achieved without resorting to extremely large or small sprockets.

Design power is the normal or average power to be transmitted by a drive system. It takes around 15 horsepower to cruise a motorcycle at highway speeds. This must be multiplied by a service factor to account for uneven or shock loads, pulsating power sources and load reversals. All these are present for bikes. A service factor of around 2.0 is typical, so the chains should be capable of transmitting 2 x 15 = 30 hp.

A three-strand 3/8-pitch primary chain reaches its maximum power carrying capacity at 3000 rpm on the small sprocket. With a typical 25-tooth crankshaft (small) sprocket, the capacity is 11.9 horsepower (which includes the service factor of 2.0).

Dyno tests conducted previously by the *Motorcycle Repair Manual* staff have shown the corrected rear-wheel horsepower developed in high gear at 3000 engine rpm (about 50 mph) by some common machines to be:

BSA/Triumph 750............16 hp
Honda 750 Four...............19 hp
Norton..............................23 hp
H-D Sportster...................30 hp

This looks reasonable. These listed powers are for full throttle at 3000 rpm, and it doesn't take anywhere near full throttle to cruise one of these bikes at 50 mph. The 11.9 hp chain capacity is quite adequate here.

The difficulty is that as crankshaft speed increases beyond 3000 rpm the engine power goes up, to the vicinity of 60 hp, while the chain capacity goes down, from 11.9 hp to only 3.2 hp at 7500 rpm. Only THREE horsepower! The situation on the rear chain is similar. At full throttle and full speed a big road bike is pumping twenty times the recommended amount of power through its chains. Is it any wonder the chains don't last 15,000 hours?

But should they last 15,000 hours? Yes, if they are to be used on a piece of equipment intended to run that long between overhauls—like a factory conveyor belt.

FAILURE MODES

Ultimate-tensile-strength, fatigue, wear, corrosion and galling are the main kinds of chain failure. Identifying the cause of failure will help you decide what corrective action to take—if any is possible. Improving a chain to resist one kind of failure usually requires sacrifices elsewhere. There's no free lunch.

Ultimate-tensile-strength measures a chain's ability to carry a steady pull. If the chain is loaded beyond its ultimate strength, the linkplates may break across the pin or bushing holes. There should be visible stretching of the metal alongside the break. A brittle failure—linkplate cracking without visible stretching of the metal—is a sign of defective steel, improper heat treating or embrittlement due to corrosion. Bushings can also fail in ultimate strength as when a loose chain jumps teeth on the sprockets. Unless weakened by corrosion, rollers rarely fail in ultimate strength. Pins may be sheared off between the pin and bushing linkplates or they may suffer brittle fracture in the center. To overcome ultimate strength failures you need a larger chain.

Fatigue-strength is always less than ultimate-strength and is related to loads that are applied repetitively. For example, as the chain moves around the sprockets, the top side is under heavy tension while the bottom side is almost slack; the impact of a roller on a sprocket tooth is another repeated load contributing to fatigue of the chain. Load reversals such as occur when you shift, accelerate, use the brakes, go over jumps and bumps or ride a bike with excessive drive train

3

1. Impending disaster. Not an uncommon sight is Japanese chain link plates cracked as shown. Caused by improper set-up, the battery vent tube was placed over this chain. Acid corrosion from the battery fumes caused this weakness caught just prior to a very expensive breakage failure.

2. Proper tools make for a sanitary job. Chain breakers range from large industrial link pin removers to a garage size to a special mini-size breaker to fit in your tool kit.

3. Spray lubes for chains have lead to ease of maintenance chores. Spinning the wheel slowly and applying the lube atop the chain lets the liquid roll down the sprocket onto the links.

snatch all add to fatigue.

When you find evidence of fatigue, replace the chain. Fatigue in sideplates usually shows up as a hairline crack that starts at a pin or bushing hole and works outward at right angles to the length of the chain. As the crack grows, its two faces rub together, giving them a burnished appearance instead of the rough, grainy texture found on cracks that happen all at once. Linkplate fatigue failures are due to too small a chain, to high frequency vibrations in the chain even when the average load is not excessive, to worn sprocket teeth or to dirt in the tooth pockets. Enlarging both sprockets in proportion (to keep the same gear ratio) will often help overcome fatigue failures.

Bushing fatigue cracks start on the inner surface of the bushing. Either they progress across the bushing where it contacts the sprocket teeth, or they go part way around it near the sideplates. Causes and cures are similar to sideplate fatigue failures.

The main cause of roller fatigue is the impact of the roller on the sprocket tooth as they engage. Jumping teeth is especially bad; it can be identified by the tooth marks or scuff marks left on the rollers. Roller fatigue is traceable to small sprockets, high chain speeds and lubrication that is inadequate to absorb the impact forces. Bigger sprockets, more lubricant and a thicker or more viscous lubricant will help.

Pins have greater fatigue-strength than sideplates, bushings or rollers. They rarely suffer fatigue failures.

Tight joints are a kind of fatigue failure in which nothing actually breaks. What happens is that the press-fit of the bushings in the sideplates loosens up, allowing the bushing sideplates to rub against the pin sideplates, making the joints stiff. Look for inadequate lubrication, misalignment of the sprockets, unusually high loads or obstacles that rub against the chain such as the chain guard, chain guide, shock absorber or a frame member.

Sprocket misalignment wear is always easy to spot since one side of the teeth will be obviously worn. In bad cases the twisting loads can destroy the chain by breaking the bushing press-fits. Both sprockets should be in the same plane when correctly aligned. Chains are tolerant and careful eyeballing of the rear chain from behind the bike is usually good enough. Check for missing or improperly installed shims on the rear and output sprockets, for a reversed output sprocket (they're not always symmetrical left-to-right), for a bent swing arm, and especially for misalignment of the rear axle in its adjustment slots. If your eyeballs aren't calibrated too accurately, a straightedge or tightly drawn string held along the sides of the sprockets will help you to see if they are in the same plane.

Wear is the one kind of chain failure that must be considered normal and unavoidable. As metal wears from the pins and bushings, the chain grows longer. This process is accelerated by the presence of desert dust, moto-cross mud and pavement particles, but very little can be done to prevent the action of these abrasives.

Eventually a chain will lengthen to where it doesn't fit the sprocket teeth and has to be replaced. You cannot measure chain wear by bowing the chain sideways as many people think, for the amount of bow depends not only on the pin/bushing wear, but also on sideplate wear due to sprocket misalignment and on the initial amount of sideplay built into the chain—which varies considerably among brands and types of chain. To measure wear accurately you must test the amount of elongation, or "stretch" (it's not actually stretch in the sense of pulling taffy, of course).

To measure *chain stretch*, lay the chain in a straight line on the floor and carefully push the links together to make the chain as short as possible. Mark where the ends of the chain are. Now hold one end at the mark and pull on the other to extend the chain as much as possible. No great force is needed. Measure, in inches, the difference in length between the mark and the extended position of the free end. For normal sprockets, this is less than three percent and the chain is still OK. But if you have a giant 80-tooth overlay on the wheel sprocket you can't use three percent since 200/80 = 2.5%, which is less. So you must compare the measured 2.59 percent to the allowable 2.5 percent. This shows the chain to be worn out since its actual percent stretch is over the 2.5 percent limit.

Wear is greatly influenced by lubrication. A dry chain wears about 300 times faster than a well-lubricated one! Even a tiny amount of oil can greatly reduce wear. Erratic lubrication allows some joints to wear faster than others which makes the chain longer in some places than in others and prevents you from obtaining a proper slack adjustment.

Corrosion is a failure mechanism that is extremely underrated. Rust will accelerate pin and bushing wear and can cause "stress corosion cracking," which is related to ultimate strength failure, or "corosion-fatigue failure," which is related to fatigue-strength failure. When corrosion and fatigue are working together to break a linkplate or pin, the telltale sign is often that there are several partial cracks near the main break. Corrosion weakens metal by destroying the surface finish.

Like piston seizures in a two-stroke engine, *galling* should not normally happen, but when it does, it's bad news. Galling means that

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the pin and the bushing pressure-weld together, then are torn apart as the chain flexes over the sprockets. This literally tears chunks of metal from the pin and bushing, causing extremely rapid "wear." Galling can be identified (on a chain you're replacing) by a mixture of bright polished and rough torn spots on the pins—just like a seized piston. Galling is always caused by inadequate lubrication *at the joint*. This can happen several ways:

First, the whole chain may be starved for lubricant because you haven't put any on. Second, the lubricant may be too thin, so that the oil film breaks down under load, allowing metal-to-metal contact. Third, the lubricant may be too thick, so that even though it's all over the outside of the chain it has failed to penetrate between the pins and bushings. Fourth, the loads may be so high that the lubricant is squeezed out from between the bearing surfaces; with a suitable lubricant, this takes loads high enough to cause ultimate-strength or fatigue-strength failures anyway, so the galling is a secondary worry.

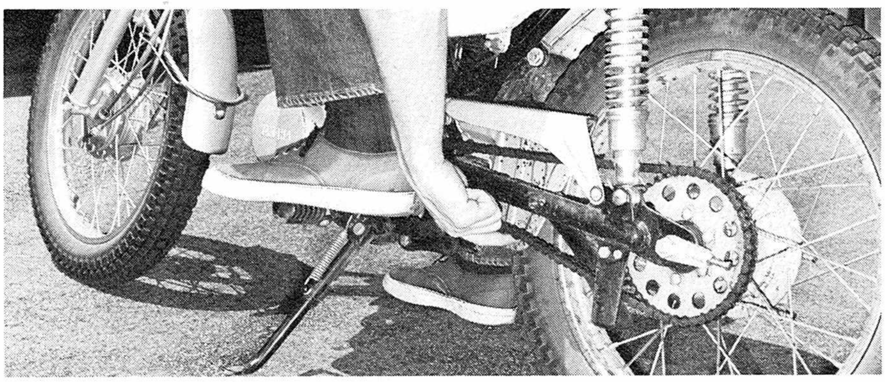
Master links are subject to ultimate strength, fatigue, wear, corrosion and galling failures just like the regular pin and roller links. In addition, they have some problems of their own. The master link is a pin link, but with the pins supported by press fit on only one side. This means the master link pins are subjected to a certain amount of bending. To reduce the chance of pin fatigue the cover plate should be a snug fit on the pins. This will support their free ends as well as possible, though not as well as a press-fitted plate. You should have to push the cover plate pretty hard to fit it on. Once in place, the plate is held on by a U-shaped spring clip or "feather" that fits annular grooves in the pins. The closed end of the "U" should point in the direction of chain motion to minimize the chance of it disloging should the chain brush against an obstacle. It is important to tap the master link pins back until the spring clip comes up snugly against the cover plate. Shop around for master links. They vary quite a bit among brands, some having cover plates that fit the pins very loosely; these should be avoided.

Press-fit master links are available for all size chains and are superior in performance, but harder to put on and take off. Since the pins are supported by press fits on both sides, and since there's no spring clip to come off, these master links are essentially as strong and reliable as a regular pin link. To put one together use a pair of Vise-Grips and place an old master link cover plate over the one you're installing: this reduces the chances of bending or nicking the press-fitted plate and allows you to squeeze it down below the ends of the pins. Put paint on it so you can find it again. Don't reuse a press-fit master link. A so-called "endless chain" is actually an ordinary chain closed with a press-fit master link.

Don't resize a chain to an odd number of pitches by using a half-link. *Half-links* are the weakest links. The pin is not supported by a press fit on either side and the dogleg sideplates are inherently weaker than straight sideplates; furthermore, they put a bending stress on the press fit of the bushing, which is likely to loosen. Half-links are inferior to regular links and to master links in both ultimate strength and fatigue strength.

To obtain an odd number of links in a chain, it is much better to use an offset link assembly, which is two or more pitches long and includes a second master link. Because the offset pitch is entirely press-fitted, its fatigue strength is greater than a half-link's, and the whole assembly is no less stronger than a master link. Fatigue is the main consideration since the offset assembly behaves like the main body of the chain in other respects. If possible connect the assembly with press-fit master links or fit standard masters with one facing inside, the other outside.

Examining an old chain can tell you which failure modes are most troublesome. If your chains fail by normal wear, there is nothing to be gained by experimenting with chains designed especially for high ultimate strength; these may wear even faster. On the other hand, if you can trace the failure to fatigue cracking, a brand or model of chain designed for superior fatigue



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strength may be the answer. Unless you have some idea why the old chain needs to be replaced, you're shooting in the dark.

CHAIN LENGTH

The stock-length chain will no longer fit your bike if you change the size of the output or rear-wheel sprocket, if you mount an overlay sprocket or if you extend the swing arm to improve the machine's handling. How do you find the right chain length to use?

The usual way is to gather a standard chain and a handful of master links, half-links, offset-link assemblies, and short lengths of chain. Armed with a good chainbreaker and plenty of patience you will eventually find some combination of parts that fits. This may take quite a bit of fiddling.

Here's a tip on installation of your new chain. Use the old one, still attached to the motorcycle, to fit the new one on. Simply connect the new chain to the old chain with a master link (you don't even need to add the coverplate and spring clip) and pull off the old chain while feeding in the new one. It's also much easier to connect the new chain's ends with the master link if the ends are both engaged on the rear sprocket.

3

1. Keeping proper chain tension is just as critical as carburetion and correct ignition timing. To make correct adjustment (usually 1 to 1½ inches free play) riders full weight should be on the machine. This will compress the rear suspension units and move the rear axle up to its normal running location without play.

2. The most accurate and best way to adjust rear wheel position and chain play is to measure the distance of the rear axle from a constant. In this case we are making the distance from the swing arm bolt to the rear axle equal. Keeps wheel straight.

3. When lubing the chain be sure to get to the link plates on the inside. Bending the spray nozzle does it.

LUBRICANTS

Nothing about roller chains is more mysterious than selecting lubricants. Besides the old standbys—oil, grease, wax, graphite—there are dozens of brandname lubricants on the market, each claiming to be the ultimate answer. Most of these proprietary lubricants are careful to avoid telling you exactly what it is that they contain, possibly because they're based on a magical formula of bat's ears, newt's eyes and chicken blood. Evidently this approach works, because most riders either continually change lubricants, always looking for that elusively perfect one, or else they've found the perfect lubricant and stand behind it steadfastly.

To make some sense out of this behavior, the first question to ask is: What is a chain lubricant supposed to do? Well, it has to reduce friction by lubricating the moving joints, primarily the pin-bushing bearing. The film of lubricant formed between the bushing and the roller is supposed to act as a shock absorber, smoothing out the repeated impacts when each roller engages a sprocket tooth and the less frequent but larger impacts of popping the clutch, shifting without using the clutch, or landing after a jump. And the lubricant must protect against corrosion which, for a motorcycle chain, means protecting it against rust. These are the three basic functions a chain lube must perform.

The outside of the roller does not need lubrication to prevent friction because the roller, despite its misleading name, does not actually roll on the sprocket teeth the way that gear teeth roll across each other as they mesh. Sideplates bear against one another where they overlap, but very little lubrication is needed here to reduce friction for the simple reason that in a properly aligned chain there is very little or no sideload to create friction in the first place. So the things any lubricant must do are to reduce friction and absorb shock inside the chain and to prevent rust on the outside of the chain.

The simplest and cheapest chain lubricant is ordinary motor oil, SAE 20 in cold weather, up to SAE 40 in 100 degree plus temperatures. All chains come from their manufacturers prelubricated—mainly to prevent rust—and oil is the usual lubricant used. Unfortunately there's a built-in conflict. Thicker oil sticks to the chain better and absorbs shock better, but thinner oil penetrates better to where it's needed inside the chain. Also, oil is not the greatest rust preventative. While all good motor oils contain additives to inhibit rust, they can do their job only so long as they resist being washed off the chain. Special rust preventatives will stick more tenaciously than plain oil.

Some old timers insist on boiling their chains in grease, a ritual based on the thin-to-apply/then-let-thicken approach to solving the conflict between thick and thin lubricants. Everybody should try this at least once. It will prove that tending a huge pot of bubbling, boiling, smoking, stinking grease is a pain in the neck. Aside from the inconvenience, a serious, often-overlooked problem is that it is easy to overheat the grease and damage it. Many greases will break down chemically at temperatures beyond the boiling point of water, irreversibly impairing their lubricating properties. Boiling in grease is best reserved as a punishment for feature editors, not as a way of lubricating chains. Don't waste your time.

The first special chain lubes were a combination of a thick oil or grease (grease is just oil thickened with special soaps) and a solvent that thinned the mixture for good penetration when applied, then evaporated to leave the oil or grease behind. This was a great advance over heating the grease to thin it for application.

The recent trend has been toward aerosol cans of brandname chain lubes whose strong point is ease of application and, let's face it, a lot more glamour than kerosene and oil. Ashland Chain Lube has an armlock on convenience with its white foam that clings to the chain when you spray it on, slowly breaking down to fluid and penetrating the crevices. Any spray-can product can be carried on a trip without danger of breaking or leaking; this feature alone may make the aerosol products worth their price.

Some chain lubricants are merely

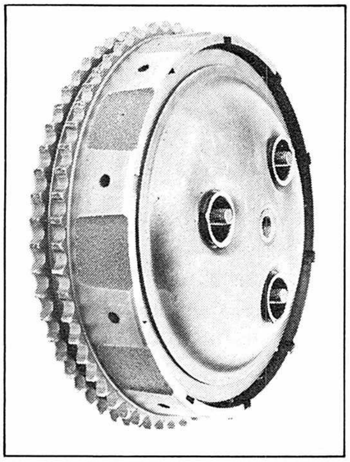
dispersions of solid lubricants like molybdenum disulphide, graphite, lead or that new miracle lubricant perfected for NASA and used on space vehicles, tungsten diselenide. Unless they contain rust inhibitors, however, solid lubricants are not very good for motorcycle chains.

Carl Shipman, the proprietor of The Dirt Rider mail-order accessory house in Albuquerque, New Mexico, sells his own mixture of dry molybdenum disulphide and Teflon for you to mix with good old rust preventing oil. He may be close to the answer. Take a look at his 12-page "Chainlube Handbook," which reiterates many of the truths found in this article and explains his lube formula completely.

You may come across industrial chain lubes that carry the idea of solvent reduction to its extreme. These are solvent reduced asphaltum or tar. Intended for large chains operating at slow speeds, these lubes are unsuitable for motorcycle use. Don't be tempted by the notion of a lube that won't fly off. Even in their thinned condition they won't penetrate the small clearances of bike-sized chain and they won't provide adequate lubrication at high operating speeds.

A relatively new, but very promising class of motorcycle chain lubricant is rust preventative spray such as LPS No. 3. The unique property of these materials is their affinity for metal. Each molecule of the "snake oil" has an almost erotic urge to couple with a molecule of strong, hard metal. If you spray snake oil onto a water-wet chain it will actually penetrate through the water in its drive to adhere to metal, displacing the water from the surface of the chain. Once bonded to the metal the rust preventative will resist attempts to wipe it off much better than ordinary oil or grease. The characteristic phrase to look for on the can is "displaces water" or "displaces moisture."

If you wash your bike at a car wash, you can blast the dirt right off the chain with the powerful detergent spray. This blasts the lubricant right off, too, and the chain will start to rust within minutes. If you squirt water-displacing snake oil on the chain immediately—waiting 'till you arrive home is too long—the rust preventative will dis-



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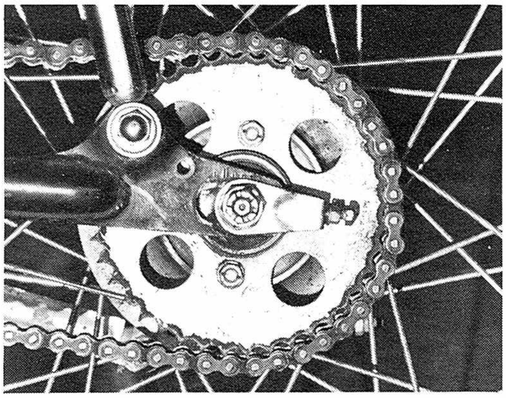

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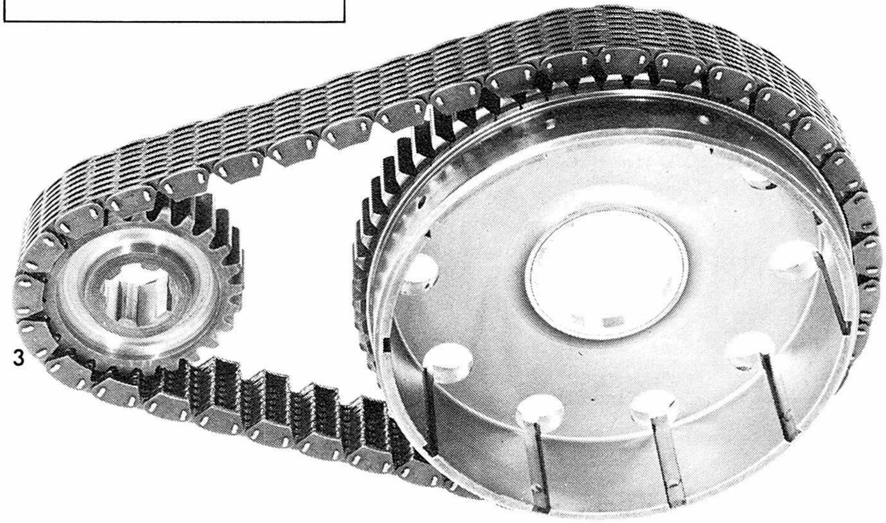

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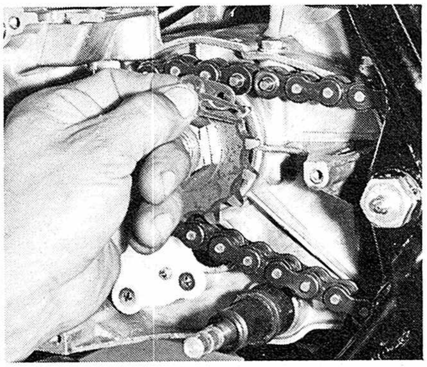
place the water, coat the chain, and nary a trace of rust will occur. Regular oil-base lubricants will protect the chain unless washed off, but they will not penetrate through water like the snake oils.

To evaluate any special chain lube ask yourself: How is this product better than SAE 20 oil (rust prevention, ease of application, penetration, etc.)? Is this advantage worth it to me? Unique advantages and disadvantages pop up when evaluating lubricants for your special purpose. For instance the desert rider who is considering a dry lubricant to reduce wear from dust and grit by eliminating oil and its affinity for these abrasives will lose oil's superior effectiveness as a shock absorber between roller and bushing; he'll merely be trading one kind of wear for another. Observations such as this only tend to complicate matters, and unfortunately, no one has the final answer. You must use the criteria presented herein to help you decide which type or brand of lubricant best meets your requirements.

Correct lubrication technique is the essence of chain care. In the first place, don't depend on a chain oiler if your bike happens to be blessed/cursed with one. All too often, built-in oilers dump too much or too little oil, they plug up without warning or fail to direct the oil where it is needed. Oiler or no, you'll still have to lubricate the rear drive chain manually to do it effectively. The primary chain and cam chain normally run in an oil bath, which is the way all chains are supposed to operate, so we don't have to worry about them.

The most effective place to apply a liquid lubricant is along the upper edges of the sideplates. This allows the lube to work down among the rollers, bushings, pins and sideplates. It's pointless to squirt lubricant on the rollers along the centerline of the chain.

The neatest, most convenient and most effective way to lube a chain with an oil-spout or an aerosol-can plastic-snorkel tube is to raise the rear wheel off the ground by lifting the bike on a shop stand or if you're lucky, merely on its own centerstand. Slowly turn the rear wheel backwards so the chain comes off the bottom of the wheel



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1. Stretched chain can raise havoc with sprocket teeth. In this case the chain stretch was so great that the rollers overlapped on the teeth (from 9:00 to 12:00 o'clock) and ripped off the tips. Ruined the clutch.

2. This is what excessive chain stretch looks like. The only place the chain is fitting is at 2:00 o'clock. Both chain and sprocket are ruined.

3. More and more machines are going to the use of Hyvo chain for the awesome task of primary drive for superbikes. This multi plate chain runs on straight teeth sprockets, is quiet, super strong and bulletproof. Hyvo chain must run in an oil bath.

4. When replacing the master link plate and clip, place the open end of the spring clip trailing the forward travel direction of the chain. Putting the open end of the clip in the direction of travel invites its getting opened by a bush or . . .

sprocket and moves toward the engine. Now spew the lubricant on the side of the sprocket just above the chain's sideplates. The lubricant will run down onto the upper edges of the sideplates—which is exactly where you want it to go. If you try to spray the edges of the chain while they're in midair between the sprockets, you'll waste most of the lubricant and make a big mess on the bike and floor. Now repeat the process on the inboard side of the sprocket, oiling the other row of sideplates.

You can reach the inboard side of the sprocket through the wheel spokes, not too hard with a long-spouted pump-type oil can, but perhaps a bit awkward with an aerosol can. Here's a trick to simplify reaching the inboard side with a spray can. Take the slim plastic tube off the nozzle and hold it at one end so it slants up at about 45 degrees. Now hold a lit cigarette under the tube about 1/4-inch from its free end. The tube will soften and the last 1/2-inch will bend straight down from its own weight. This leaves you with an applicator tube that bends back on itself at the end. Putting the tube back in the nozzle, you'll find that you can reach the inboard side of the chain from behind and below the wheel sprocket, and the tube still works OK for the outboard side. Using this method, the hardest part about lubricating the chain is getting the bike on and off the stand.

How much lube should you apply? If the chain throws oil all over the bike—and you—you're applying too much at one time. If you're using a solvent-reduced lubricant, give it a long time to thicken before you ride the bike—like overnight. The best time to lube a chain is just after you've completed a ride. Not only does this give the solvent plenty of time to evaporate, but also the chain is warm and the lubricant will penetrate more freely. The worst time to lube is just before you go riding. After the freshly lubricated chain has set a while, say the next morning, wipe it off lightly with a rag. This will not remove the thin film of lubricant necessary for rust prevention, but it will get rid of the excess lubricant that would otherwise fly off while you're riding.

How should the chain be prepared for lubrication? As we said before, there is always a certain amount of abrasive debris irretrievably lodged in the pin/bushing joint and under the roller; the undesirable effects of its presence are unavoidable short of boiling the chain every 10 miles. External washings under pressure can purge most foreign matter from between overlap portions of the sideplates, the only other place dust and grit is harmful, but this area will only stay clean briefly and the chain must be sprayed immediately with water-displacing snake oil to prevent rust.

How often should you lubricate? Conditions vary so widely that no set number of miles or days is an adequate guideline. You have to adapt the lubrication cycle to the particular conditions under which your chain operates. The type of lubricant you're using, the amount of dust in the air, how fast you ride, air temperature, the power-carrying capacity of the chain, the sprocket rpm, the chain pitch and even the brand of chain influence the length of time a chain can go until it needs lubrication. You have to take all these things into account remembering that the common error is to try to make up for too infrequent lubrication by applying too much lubricant at one time.

A properly lubricated chain will never rust. Allowing it to rust is a serious business. The finely-ground surface finishes are destroyed, which means the chain has to break-in all over again after being lubricated. If this cycle is repeated the chain will suffer abnormally fast wear-out. Furthermore, corrosion weakens the highly heat-treated steel, making the linkplates susceptible to corrosion-fatigue cracking. Your chain will be as well-lubricated as you can keep it if you apply a little bit of lubricant frequently enough to suppress traces of oxidation.

You can see why boiling a chain in grease is so inefficient. It's such a messy, cumbersome business you're not likely to do it often enough. Amount of lubricant is no substitute for frequent, properly applied lubrication. The greatest advantage of spray can products may not be their magical secret ingredients, but that the very ease of using them encourages the average rider to lubricate his chain more often. Lubrication frequently enough to keep the rust away—even with bacon drippings—is better than infrequent lubrication with the latest miracle product.

ADJUSTMENT

Proper adjustment is a large factor in efficient operation and longer chain life. Multi-strand or Hy-Vo primary chains wear rather slowly since they are enclosed and bathed in oil. Some are adjusted with slipper followers according to the manufacturer's shop manual while others have no provision for adjustment at all and are replaced when slack exceeds the specified maximum. Cam chains must also receive frequent inspection for proper tension and compensating adjustment if necessary; tensioning devices are usually external, as on Honda Fours, and easy to use. But the heavily loaded—often overloaded—poorly lubricated, and exposed rear chain requires continual adjustment during its short, brutal life.

A tight chain places heavy loads on the shaft bearings, the sprocket teeth and the chain joints, causing abnormally fast wear of all parts. On the other hand, a loose chain vibrates and surges causing exces-

sive wear and noise, and it snaps like a whip under impacts, possibly snapping itself apart. Proper adjustment treads the narrow line between too tight and too loose.

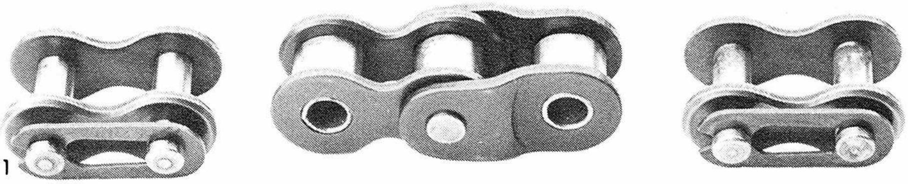
How to align motorcycle wheels so both are exactly in the same plane and tracking straight should be the subject of detailed explanations. But for some reason it's always passed off by suggestions which range from eyeballing down the top run of the chain to laying a two-by-four along both wheels and juggling the rear axle adjustment until the tires look parallel with the board. Bunkum. In the eyeball method a chain can look straight but the wheel can still be crooked, and in the board method there is no way you are assured the front wheel is pointing exactly straight before lining up the rear one.

Assuming the frame was made in a jig and therefore the front wheel is always aligned properly and the swing-arm pivot axle is at exact right angles to the front wheel, there is a way to assure perfect rear wheel alignment. Simply measure the distance from the swing-arm pivot point to the rear axle on both sides of the machine. When this distance is equal to the millimeter, and it is best to measure from the center of both shafts, then alignment is correct. Measuring may be hindered by exhaust pipes or footpeg mounts which require bowing of the measuring device (usually a steel tape) which of course makes a longer reading. It may be wise to drill and tap the shafts enough to extend their centers with threaded dowling beyond any possible obstructions to accurate measurement. A lot of effort? Not when you consider wheel alignment means even more to handling and safety than it does to the chain.

For years there's been a poorly worded rumor going around about *chain stretch*. A chain operating anywhere near its design load and speed doesn't actually stretch, like a pair of old shoes, but it grows longer as metal wears away from the working surfaces. Only .005-inch of wear on each pin and bushing "stretches" an average chain by a full inch. Recall that a chain is worn out when its measured stretch is about three percent of its length; using it beyond this point invites failure and damages sprocket teeth.

Many riders will remove a couple of links from a worn chain so that they can continue to use it even after the axle has reached the end of its adjustment slot. If you do this, better take a look at those numbers again. Figure out what part of an inch .015PL is for your bike. Say it's .675-inch. With a properly adjusted new chain installed, measure the amount of remaining axle travel. Suppose it's 3/4-inch, a reasonable amount. This means the chain will be worn out before it develops so much stretch that the axle hits the back of its track as you try to adjust the chain. If the axle travel available when the chain is new is only 1/2-inch, then you can remove two links when you run out of axle adjustments and continue using the chain a while longer, until the total takeup is about .675-inch.

When chain stretch exceeds three percent, the tension is concentrated on only a few sprocket teeth instead of being spread out over many teeth. This wears out the sprocket. The teeth develop an easily identified hook-shape. This hooking increases the effective pitch of the sprocket, so it will quickly damage a fresh replacement chain...again, by concentrating the load on a few rollers instead of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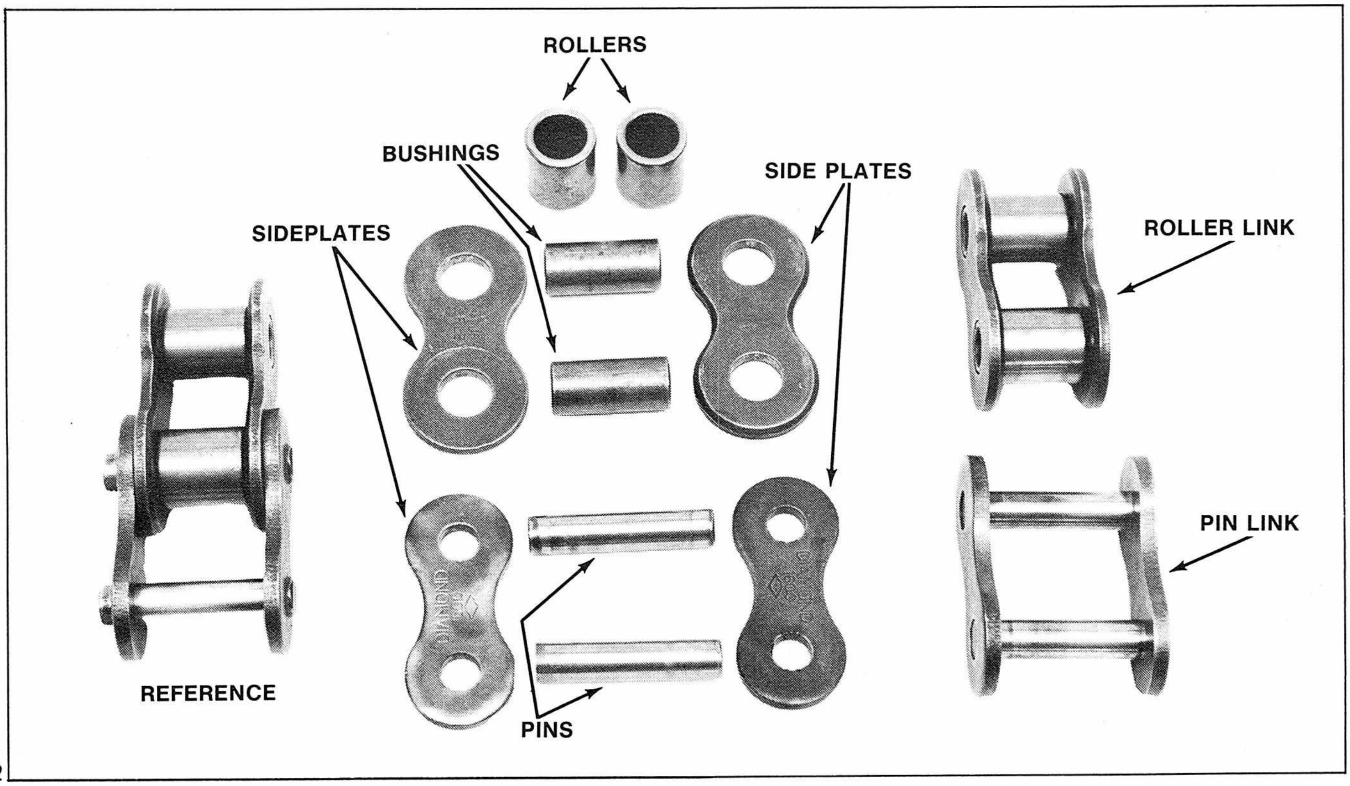

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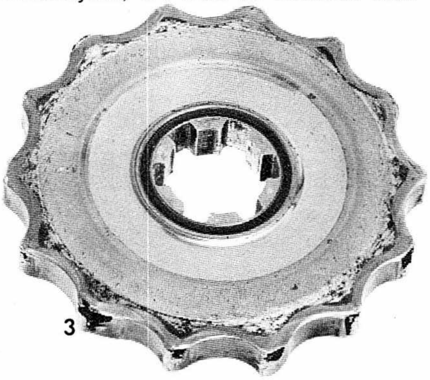
spreading it out over many. Under normal circumstances, replacing the chains before they exceed three percent stretch, a set of sprockets will last for from three to five chains—unhardened sprockets with few teeth wear faster. Any visible amount of hooking means the sprocket is worn out. If you try to squeeze more use out of the original equipment chain on a brand-new bike, by removing links as slack forms, you can easily destroy the sprockets with this first chain. From that point on, the misshapen teeth will chew up replacement chains faster than a Pike can munch a Minnow.

Also, never install a new link in a chain that has been appreciably elongated by wear. The pitch of the new link will be shorter than that of the other links, and the resulting shock each time the link engages the sprocket will soon destroy the chain. The shorter link will wear hard on every tooth it contacts and sometimes can set up chain whip.

If you buy a bike new don't indulge the false economy of trying to make the original chain last as long as possible. Often the original equipment chain is not as well made as the replacement chain your dealer stocks in bulk. Replace the chain when axle take-up reaches .015PL. If you buy a used motorcycle, it's safe to assume that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1. Shown (middle) is an offset link assembly with master links. This should only be used to make up odd pitch count in necessary cases. Though superior to half link in strength, should be avoided when adjustment will give even pitch count.

2. Exact picture of chain construction will help you understand importance of proper chain maintenance. Top to bottom; rollers, bushings flanked by roller link plates and pins flanked by pin link plates. Individual links at right join to form complete chain link assembly on the left.

3. Unattended chain wear led to the complete destruction of this countershaft less teeth.

the chain that's on it, or a previous one, has been run too long, damaging the sprockets. So when you decide to replace the chain, replace the sprockets, too. At least the small output sprocket, for it takes a worse beating than the larger sprocket on the rear wheel.

Your best defenses against chain failures are frequent lubrication, adjustment for minimum (but never zero) slack and replacement of both chains and sprockets before they're excessively worn. It's bad enough to sit out a race or to find yourself stranded because of a broken chain (Murphy's Law: On any trip, the chain will break at that particular point along the road which is farthest from facilities to repair or replace it.); but the real disaster is for the broken chain to bunch around the output sprocket and destroy the crankcase castings. This can be big troubs. You can buy an awful lot of chains and sprockets for the price of a new crankcase—assuming you can get one, that is. So accept the fact that the rear drives on motorcycles are almost always underdesigned, and the chain and sprockets have to be replaced periodically like tires or brake linings. The life you save may be your crankcase's. On rare occasions a broken chain may even wrap around and lock up the rear wheel. Granted this is not probable enough for you to lose sleep over it, but there still remains an outside chance that the life you save through proper chain maintenance may just be your own.

SPECIAL CHAINS

There are several kinds of special chains which may or may not have advantages for motorcycle applications. Let's take a look at some of them.

Yankee Motor Company, the Ossa distributor, has recently introduced their "Full Bore" line of 1/2-inch and 5/8-inch motorcycle chain manufactured especially for them by Union-Whitney. It has a carefully considered trade-off between wear rate and fatigue strength suitable to the conditions on a motorcycle. The most novel feature is the patented master link. Instead of pressing both pins into one sideplate and slipping a spring-clip retained coverplate over the other end of the pins, the Yankee master link is made in two identical parts. One pin is pressed into each sideplate, forming an L. The two L's are slipped together and held with two spring-clips, one on each side of the master link. This remarkable design reduces or eliminates bending stresses on the pins. Furthermore, both clips must be removed to disassemble the master link. This increases reliability. It is hard to imagine both clips breaking or being knocked off at the same time. It will be interesting to see how this new master link works out in practice.

The Daido Corporation imports plated chain that is made by a novel, secret process that allows the chain to be plated after assembly. This cuts manufacturing costs and lowers the price to a level competitive with conventional chains. Marketed in Southern California as Superchain, field results have been encouraging. Superchain resists rust very well which leads to long life under the realistic conditions of water crossings, rain, and carwashes.

One final kind of chain should be mentioned even though it is not a roller chain at all. This is *Morse Hy-Vo chain*, a modified version of automotive silent timing chain. Expensive and requiring special sprockets, Hy-Vo has the one great advantage of transmitting high power at high speed through a very compact drive. It's best known application is on the front-engine Oldsmobile Toronado. The same type of chain is in the Honda Four primary-drive system. Its design minimizes chordal action and is well-suited to use with the pulsating drive of a piston engine. A one-inch wide, 1/2-inch pitch Hy-Vo chain can transmit 75 hp at 5000 rpm with a 25-tooth small sprocket. For comparison, a two-strand No. 50 roller chain running at 1500 hp on a 25-tooth small sprocket has a maximum capacity of only 38 hp...half the power with a physically bigger drive. When all else fails on those multi-engine drag bikes and Bonneville record machines, Hy-Vo may be the answer.

Chains are complex mechanisms that need constant monitoring and care to prevent premature failure and ensure long life. Replace them before you reach the borderline of failure due to wear, and before that point, care for them with dedication.

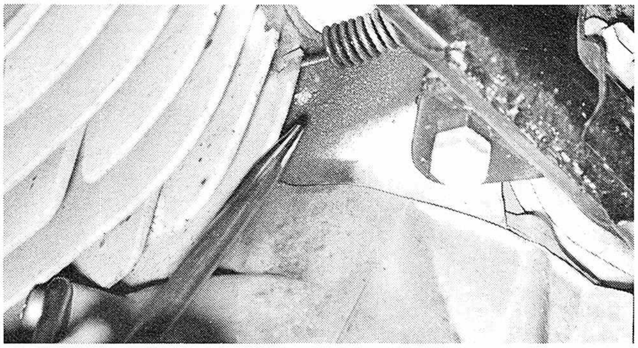
TWO-STROKE ENGINE REBUILDING

Simple and compact, the modern two-cycle motorcycle engine is a dream to work with

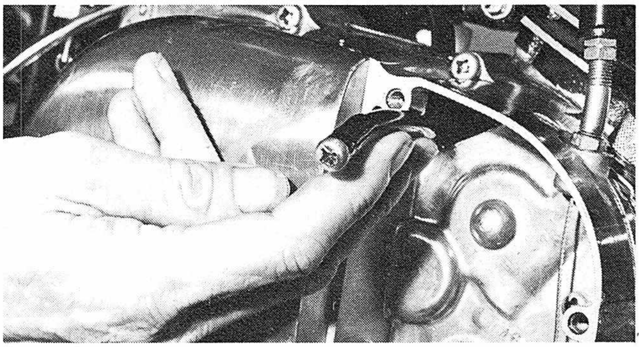
Motorcycles lend themselves to an inordinate amount of fiddling by amateur mechanics when compared to a car. One projection as to *why,* is that everything mechanical is exposed to view and not hidden under a protective layer of sheet metal. In the "Good Old Days" prior to World War II, a motorcyclist had to exercise equal parts of brawn, courage, patience and mechanical aptitude. A leisurely ride often led to major roadside repairs and few garage mechanics knew anything about bikes.

Nowadays the tinkering and rebuilding is usually done for sport rather than out of necessity. Many manufacturers, like Yamaha, have sophisticated, reliable machines that can be ridden thousands of miles. Among the two-strokes built around the world are a variety of bikes from, super-simple 70cc two-stroke singles to massive 750cc three cylinder models with water cooling and an electric starter.

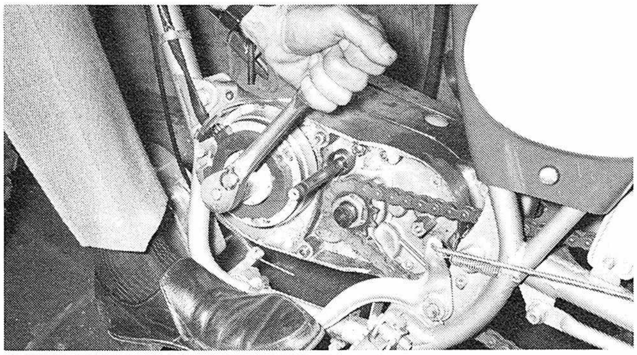
HOW TO: Overhaul Your Two-Stroke



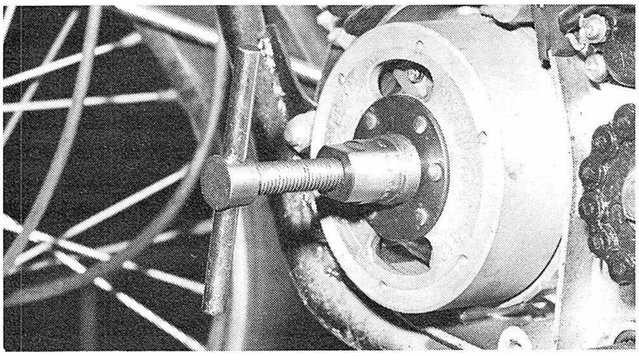
1. Remove the exhaust and intake systems first. Before pulling off the exhaust pipe remove the retaining springs.



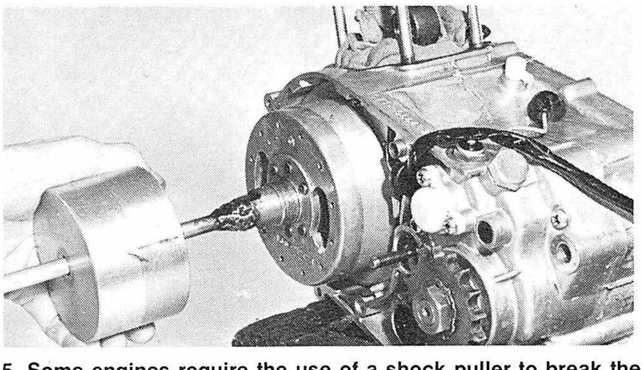
2. Engines with oil injection systems should have the pump removed and the inlet and outlet lines plugged.



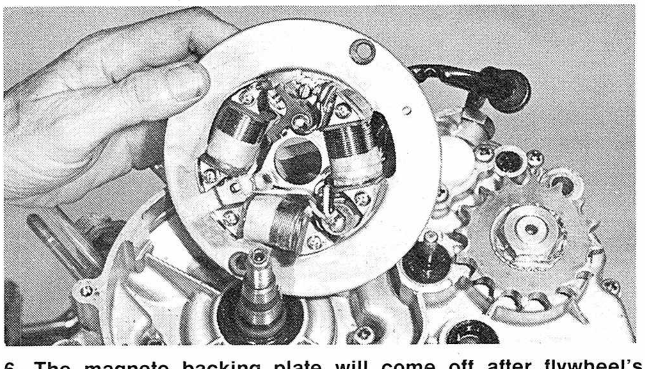
3. A simple method to remove flywheel or clutch nut is to lock the rear brake. This keeps the engine from turning.



4. Don't try to remove flywheels with anything other than a factory puller. Hodaka puller fits most Japanese magnetos.



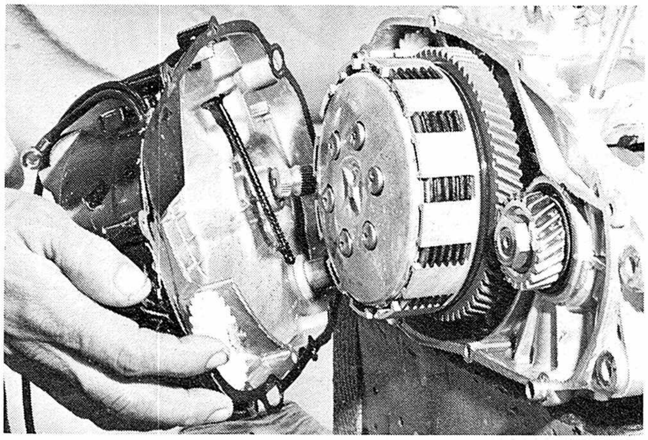
5. Some engines require the use of a shock puller to break the seal of the flywheel from the tapered crank end.



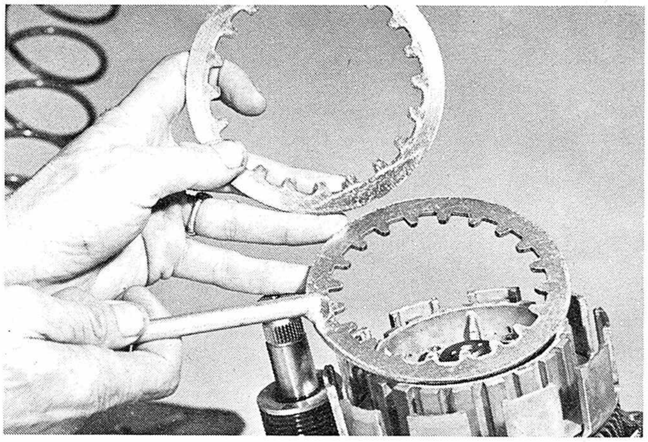
6. The magneto backing plate will come off after flywheel's removed. Set the backing plate and wires out of the way.

Unfortunately, most weekend tinkerers are unaware that even the simple two-stroke requires more than elementary wrench twisting when it comes to a major overhaul. The two-stroke engine has progressed by leaps and bounds over the past few years. The introduction of automatic lubrication has eliminated the necessity of pre-mixing gas and oil, increased reliability and longevity and helped to wipe out exhaust smoke. But with the virtues comes added complexity and a new need for special attention during an overhaul. Now even some small two-stroke singles, like the Yamaha 70cc street bike, include such sophisticated items as a built-in electric starter.

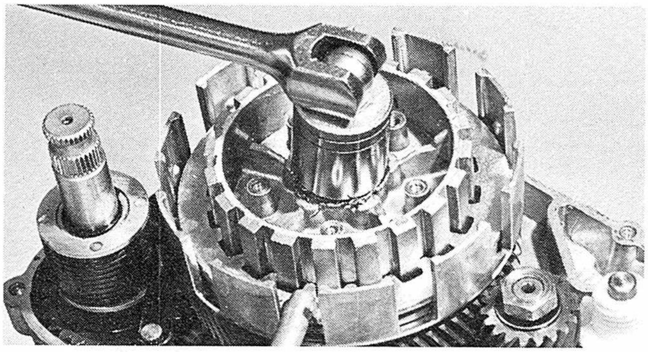
The motorcycle is still basically a simple machine to work on when compared to the standard automobile, but don't get the mistaken idea that a complete overhaul is just an easy matter of taking it apart and putting it back together again. Today, most motorcycle repairmen are specialists in their fields. You will find that a Yamaha mechanic is best suited for working on Yamahas, and Honda mechanics on Hondas, and on down the line. The reason for this is that these large manufacturers now offer service schools that deal with the specific problems and characteristics of their engines. The shop mechanic must have the theoretical knowledge and skills necessary for working with close tolerances. It is possible for the backyard mechanic to do much of his own repair work, but major overhauls including disassembly of the crank should be done by a professional. If the overhaul is done correctly, the result will be an engine that is capable of living out a life as long as that of the original engine. If the job is done incorrectly, the consequences could be in hard starting, knocking noises, plug fouling and an owner who is firmly convinced that the only way to



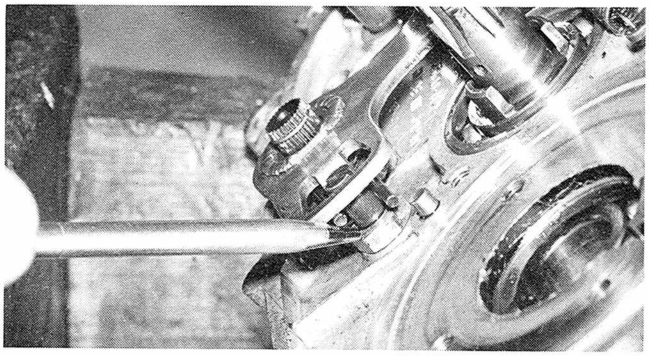
7. Be sure the transmission oil is drained, then remove the cover. Plan on using a new gasket and oil.



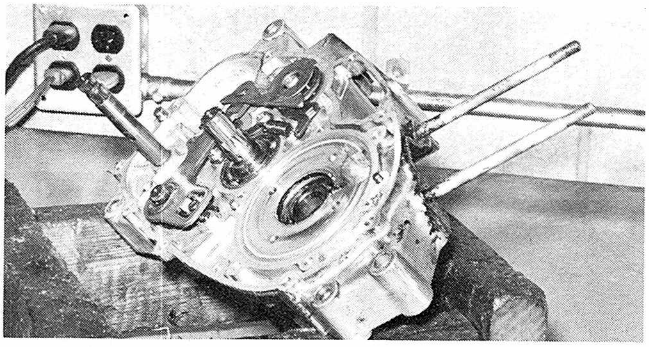
8. You can buy or make your own clutch holding tool. It's the quickest and safest way to remove it without damage.



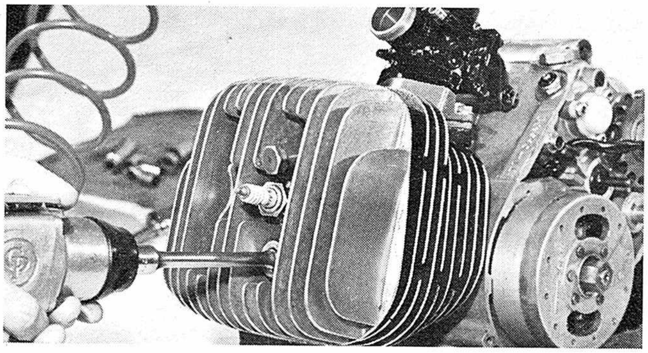
9. Before you remove the clutch hub nut, be sure to flatten the locking tab. Jamming the gears is not recommended.



10. Removing the clutch on most Japanese machines will expose the shift mechanism. Don't loosen the eccentric screw.



11. One of the handiest special items is this 12 x 12-inch working stand made of two-by-fours for engine case work.



12. With externals removed, the head and barrel are next. Power driven wrenches are fast but can over-torque.

go would be to buy a new machine. Actually, the engine well might be rebuilt better than new if proper techniques are followed and close tolerances are kept.

In many instances, repair of a specific portion of the engine—such as cylinder honing, boring and wrist pin replacement—can be done while the engine is still in the frame. An extensive overhaul requires the engine to be removed from the frame. All wiring must be disconnected, the exhaust pipe and fuel lines disconnected, and linkages and all obstructions removed. Unless you are familiar with the mechanical intimacies of the motorcycle on which you intend to work, it is a good idea to purchase one of the many excellent shop manuals available on the market for your particular machine. Otherwise you should disassemble the machine with extreme forethought, marking any parts that you feel you cannot replace accurately during reassembly. A marked strip of masking tape on all electrical wires will readily identify their location. Most new machines have wires that are color coded to simplify reassembly procedures. For instance, a yellow wire reconnects with a yellow wire, red to red, etc.

Prior to removing the engine from its frame you can simplify the coming teardown work by constructing an engine stand. This stand can be made

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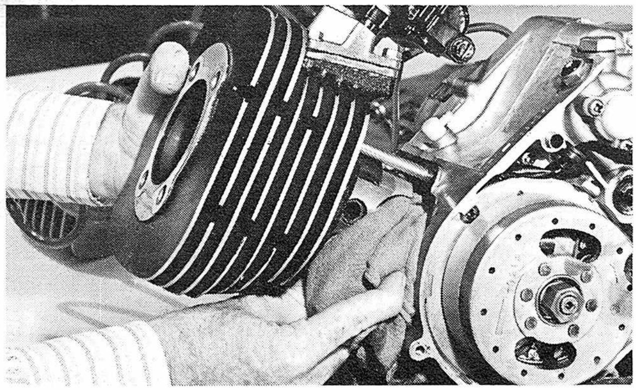
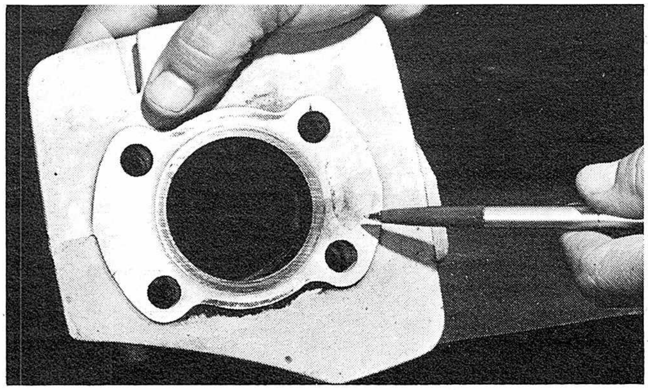
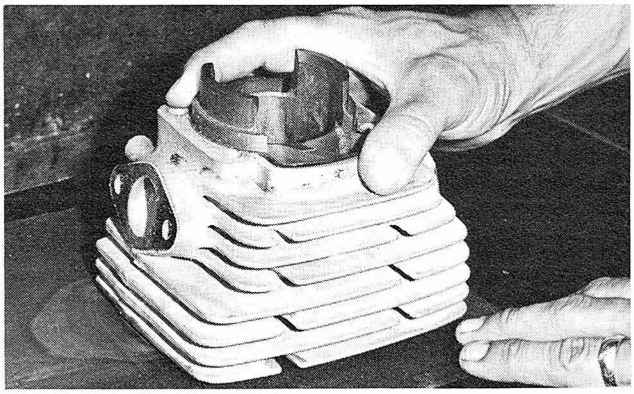


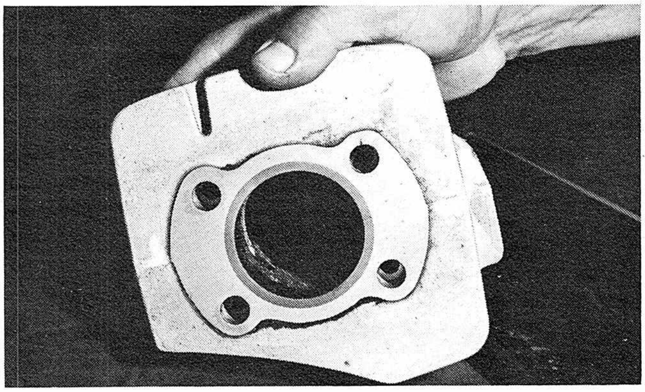
13. After the head is removed lift off the cylinder. Be sure to cover the crank opening to catch broken rings.



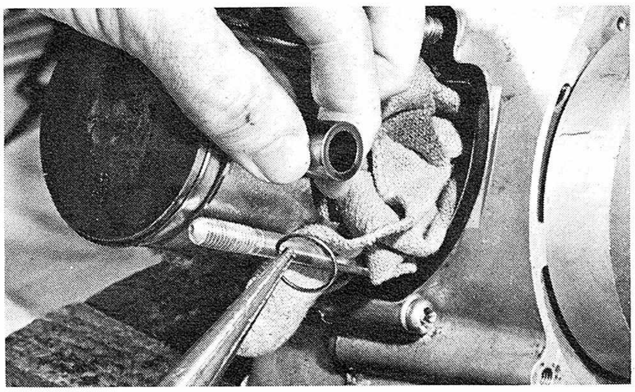
14. Inspect the top surface of the cylinder for leaks, gouges or cracks. Occasionally the sleeve will move up.



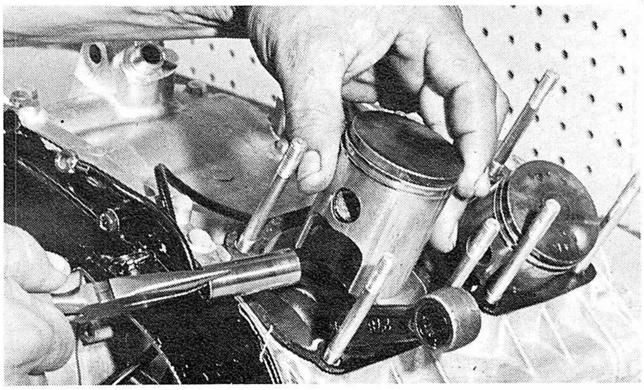
15. It's always a good idea to hand lap the surface to insure a leak-proof seal of both cylinder and head.



16. Just a few strokes on some emery paper laying on a flat plate will give the cylinder top a perfect surface.



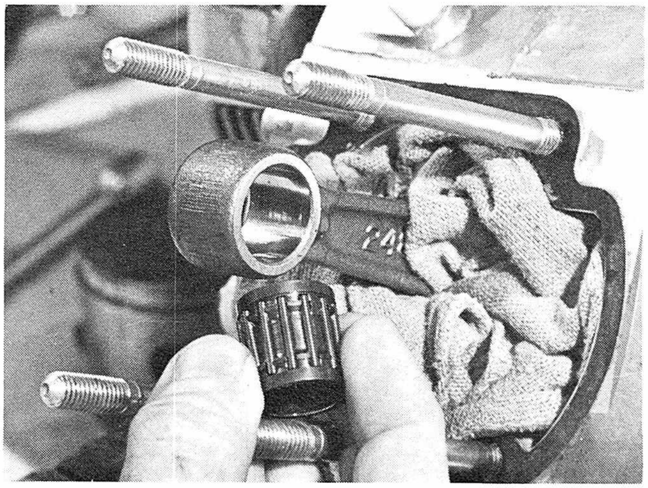
17. The wrist pin should be a thumb press fit coming out and going in. Don't damage the bearing by driving it out.



18. When installing the new piston, the pin fit should be snug, not minus clearance. Be sure the clips drop in groove.

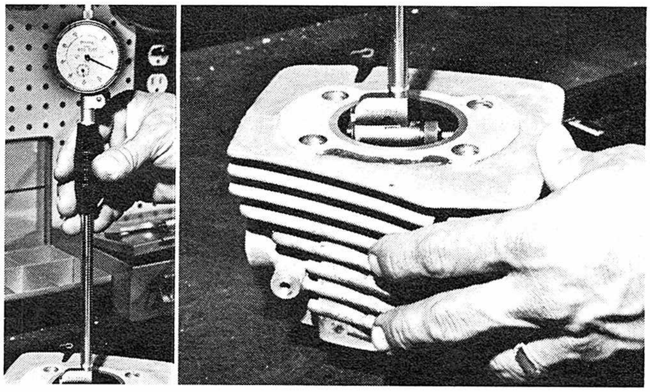
very simply of sections of 2x4-inch or 2x6-inch wood nailed together in a 1x2-foot box, and is essential for your working on the engine in the most efficient manner possible. With the engine out of the frame, careful disassembly can now take place. A novice mechanic should note that whatever comes off the engine first will be the last to be reassembled. Unless care is taken, you can misplace some simple but very important small pieces, such as nuts or brackets. Small jars or boxes are extremely helpful in keeping together parts from a specific area. For instance, bolts that hold carburetors in place should be cached in a sealable container and marked for future reassembly. During disassembly note the sizes and number of the screws or bolts involved, and positioning of any irregular pieces such as oddly-shaped gaskets or hinge bolts. Haphazardly destroying an engine piece-by-piece will result in a basket case that will cost more money to put together than if you had taken the complete engine to a professional mechanic to begin with. Any mechanic will tell you that it is far more difficult to try to reassemble a "basket case" than it is to work from scratch in a methodical manner.

Any group of parts or major components should be cleaned of grease or oil as they are removed from the engine. The cleaner you use can be one of the many solvents available at

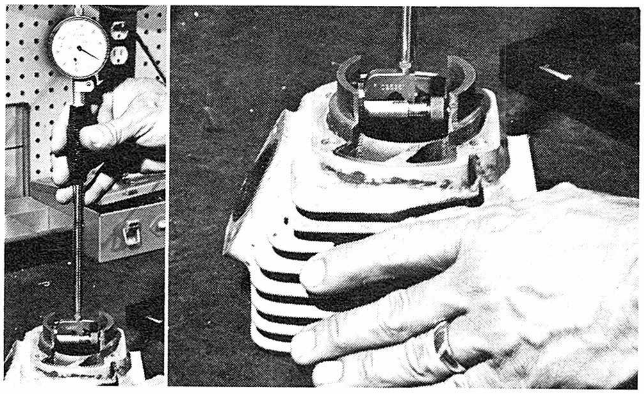


19. Carefully inspect the needle bearings, bearing cage and rod bearing surface for flaws. Replace if in doubt.

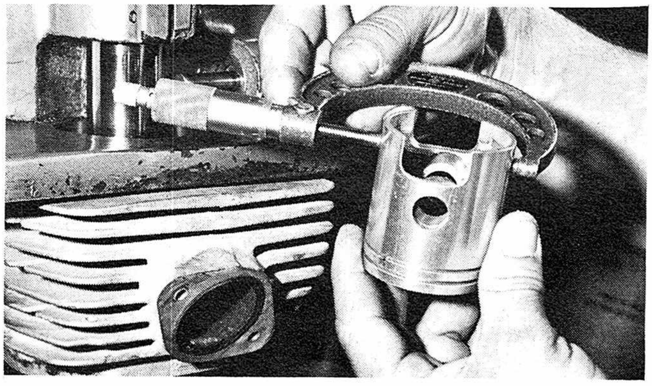
20. If there's a lot of miles on the engine, piston scuffing will be normal. Galling indicates a seizure and reboring.



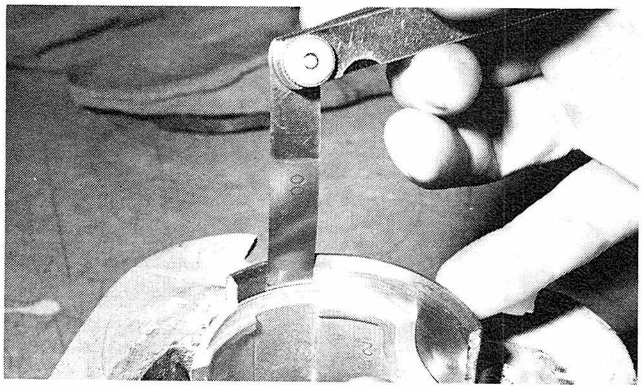
21. Checking the bore diameter and taper requires an inside micrometer to be exact. Check bore roundness also.



22. A reading from the bottom and top gives amount of taper. Over .002-inch means rebore to next oversize.



23. Always size a new piston by measuring here. Don't rely on measurements stamped on the top of the piston.



24. Piston to bore size will vary. Clearance for 100cc may be .0015-inch, 250cc .0025-inch and 400cc .003-inch generally.

auto supply stores. This may seem unimportant for an engine that will eventually again receive oil in the crankcase, but misplaced dirt or debris can cause serious mechanical difficulties. A small speck of dirt, for instance, could cause leakage between gaskets. It is common knowledge that dirt can rapidly destroy bearing surfaces and shorten the life of any engine.

All this cleaning may seem like unnecessary extra work but no part can be accurately inspected if it is either dirty or greasy. Obviously, a badly damaged part need not be super-clean to verify the need for discarding, but most failures are generally small and difficult to see at their onset. It must be remembered during inspection that continual workloads on any mechanical assembly will eventually lead to a failure of that part. Locating areas of potential failure is one of the keys to successful engine rebuilding and the primary reason most professionals will submit suspect parts for a magnaflux inspection. Magnafluxing is a relatively new technique to motorcyclists and is used in locating fine-line cracks that are invisible to the naked eye. Components most eligible for magnaflux inspection usually include the crankshaft, connecting rod and, in the case of the four-stroke, the camshafts and rocker arm assemblies.

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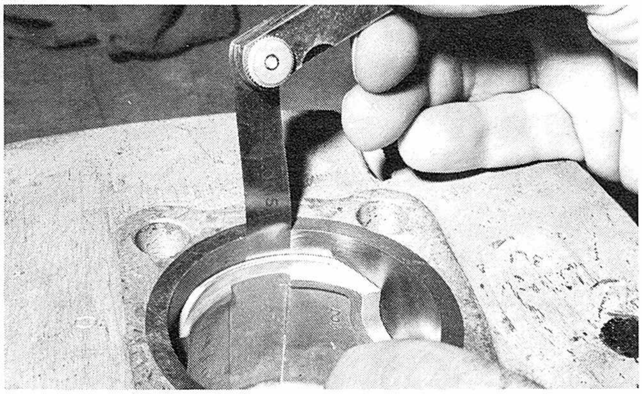
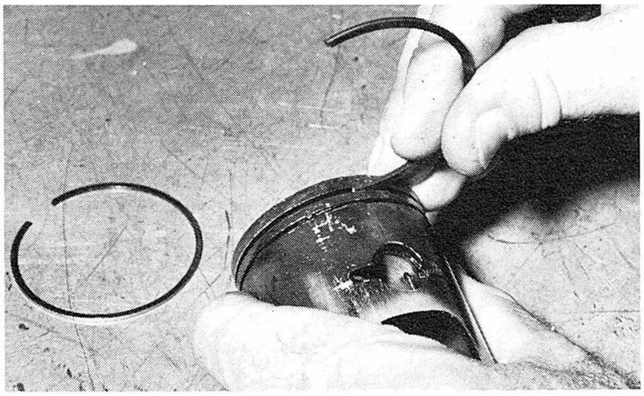


25. Check piston clearance at the top also. Run the feeler gauge and piston 360 degrees around the bore diameter.

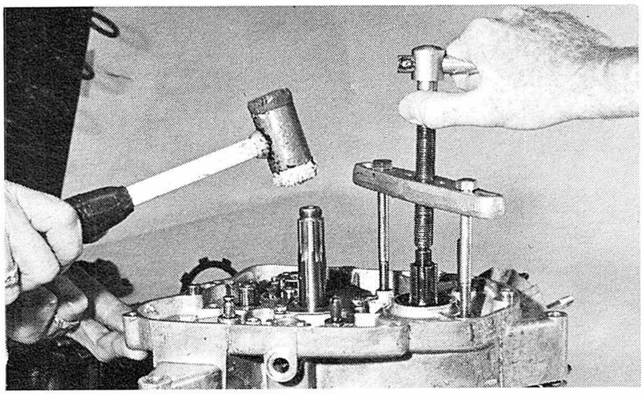
26. If you can save the old piston and bore be sure to remove all carbon and sludge. Will increase heat dissipation.



27. It's always best to replace rings. Cleaning the ring grooves is easily accomplished with sharp broken ring.

28. Condition of the big end is checked by trying to move the rod up and down while holding it against the flywheel.

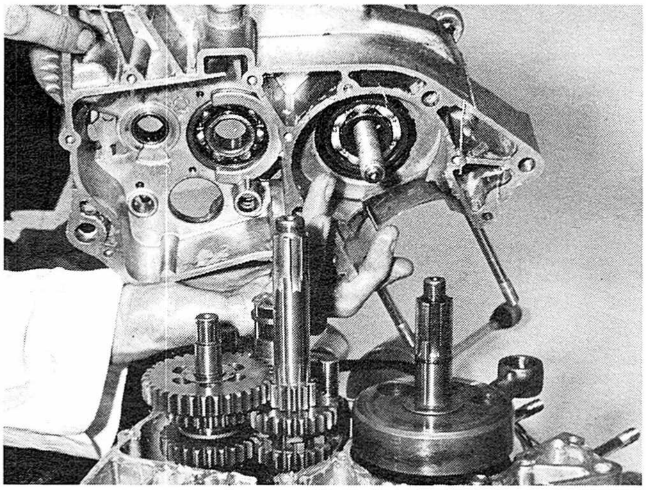
29. If there's no up and down play, check for recommended side play. If it exceeds factory specs, rebuild the crank.



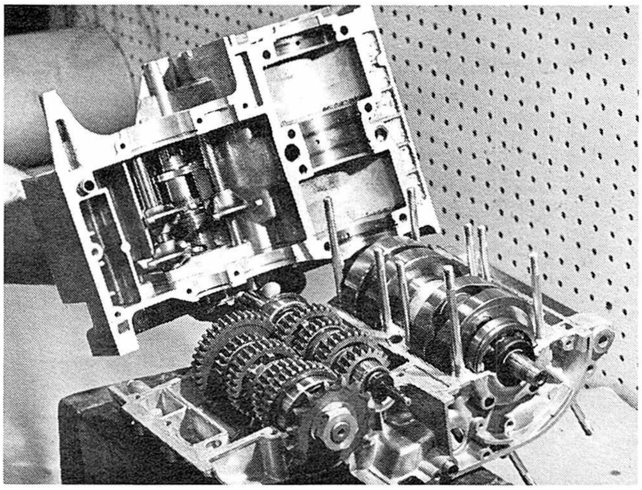
30. Most Japanese engines that split vertically will require a puller to separate the cases without damaging them.

Next in line of suspicion is any point where metal-to-metal contact is evident. Some degree of wear is normal and expected in any engine. A good shop manual will give upper and lower limits of wear to help the mechanic determine when replacement is necessary. Premature or excessive wearing of any component is a good indication that the oil supply is inadequate. Here the mechanic must suspect that the oil pump is not functioning properly or requires adjustment. In any area, minimum wear will appear as a polished surface such as found in the cylinder bore. A surface blue from excessive heat is also a good indication that there has not been adequate lubrication.

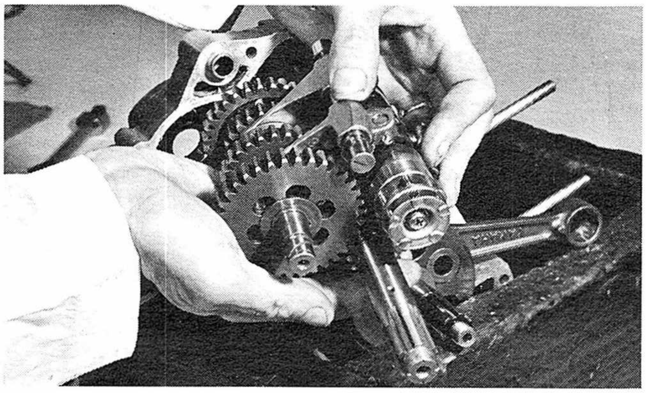
The basic tools required for accurate measurements are a dial indicator, feeler thickness gauges and an inside and outside micrometer. The standard micrometer is used for linear outside measurements from .001-inch or better. For convenience sake, a micrometer can be obtained that gives measurements in increments of millimeters. Most Japanese motorcycle companies now indicate both American and metric measurements in their tables and specifications. An inside "mike" is generally used for measuring the distance between two inside parallel surfaces such as a cylinder bore. When measuring the inside of a cylinder it is advisable to take several measurements in different spots to allow for any irregularities in



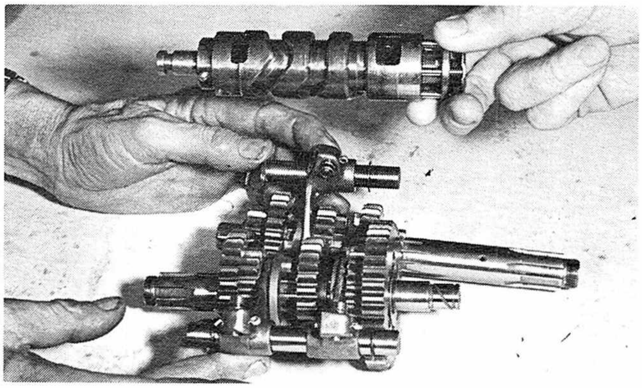
31. Once split, lift the loose case half off slowly and watch for any shims that might be on the crank or gearbox.



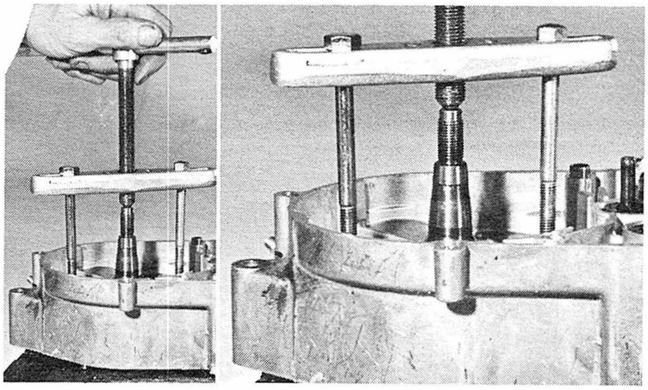
32. Remove the transmission only if necessary, although now is a good time to check all the trans bearings, bushes.



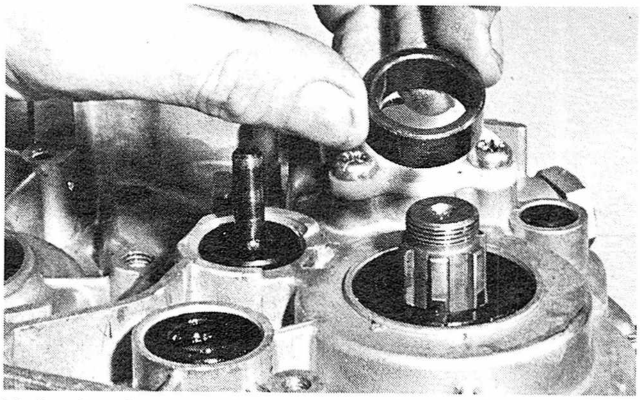
33. Engines that split horizontally are a snap to split, but more critical with torquing specs and lock pin alignment.



34. If you take out the trans, inspect the gears and shafts for galling and check the shift mechanism for chips, burns.



35. Many engines require a puller to push out the crankshaft as well as pull it back into the bearing race.



36. Don't make the fatal mistake of leaving out shims and thrust washers. Buy an exploded view drawing, follow it in detail.

the bore diameter caused by excessive wear. Feeler gauges are inexpensive, highly accurate tools that should be part of any mechanic's tool box. They come in a variety of sizes and shapes ranging from a thin wire to a flat surface used for different types of measurement. During an engine overhaul, the feeler gauge can be used often to measure piston-to-cylinder clearance, ignition point gap, spark plug gap and rod end play.

One of the first checks that should be made is measuring warpage of the heads. Most cylinder heads are subjected to rapid temperature changes that could cause warpage if the changes have been drastic enough. Aluminum alloy heads and crankcases are more subject to distortion than those of iron. A warped area between the cylinder head and the cylinder can usually be spotted quickly. Look for a darkened area caused by blowby. This type of warpage can be easily corrected by resurfacing the head on a flat surfacing stone, using emery cloth and a mild lubricant such as light oil or water. To check for distortion, lay a straight edge across the surface of the head and slide a feeler gauge between the surface of the head and the straight edge. Repeat this measurement lengthwise, crosswise, and diagonally to determine if the head is distorted or not. If distortion is excessive the

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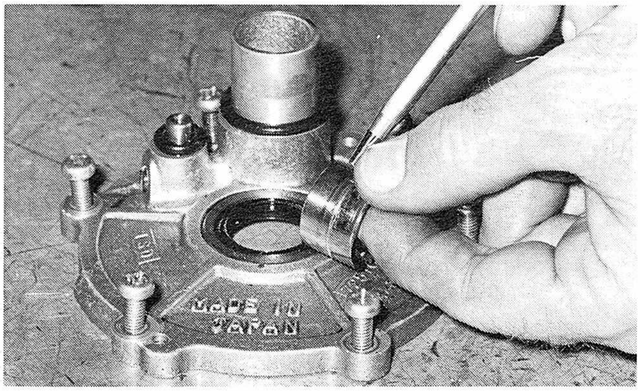
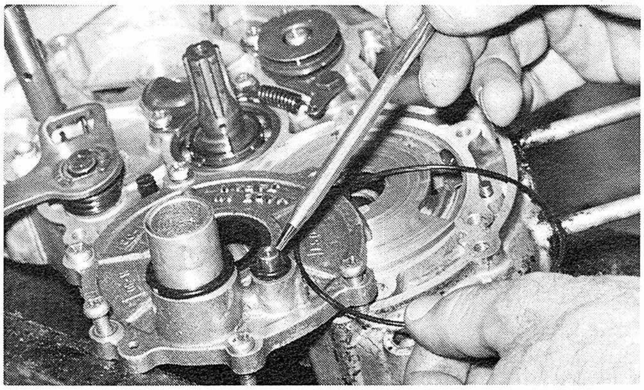
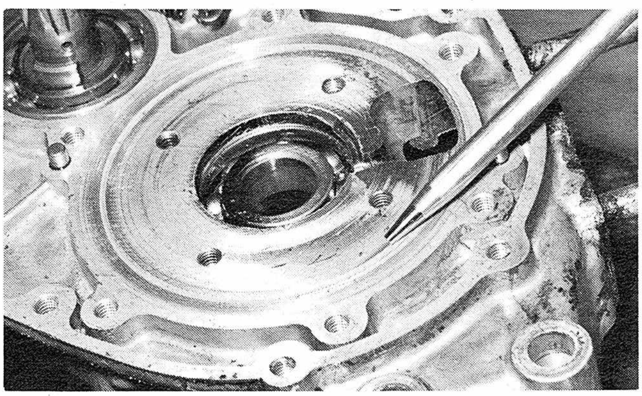


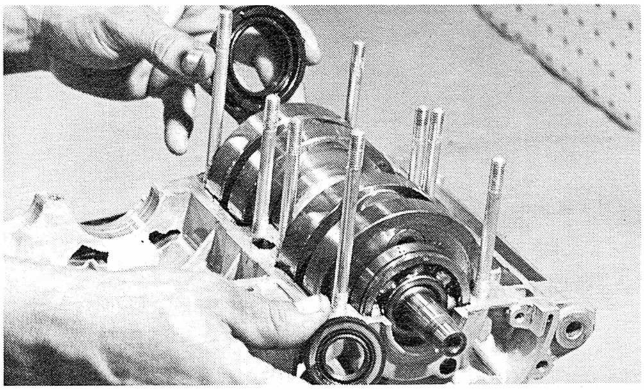
37. An engine with lots of miles will show excess wear on seal lip to metal parts. This thrust washer is worn out.



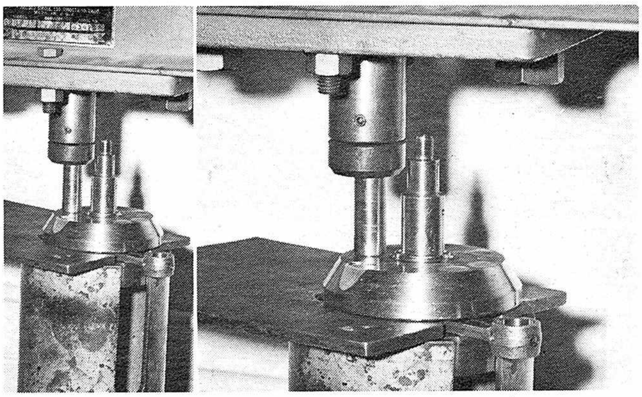
38. While the engine is down and apart it's always best to replace all O-rings with new parts. Cost is minimal.



39. Rotary valve engines will generally show wear from the spinning disc. Install a new disc, resurface manifold.



40. Always replace the crankshaft seals while the engine is apart. Their cost is small and they'll insure long life.



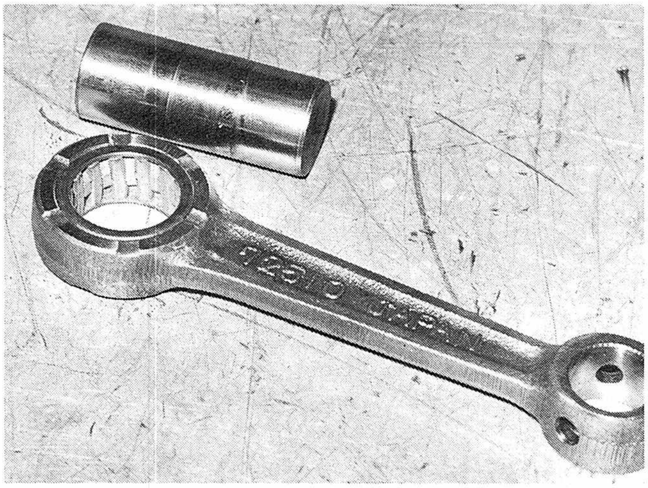
41. Regardless of engine size, hydraulic press is required to split flywheels and install new bearing, rod or pin.

42. If any play at all can be felt between rod and bearing replace the bearing. Oil generously when reassembling.

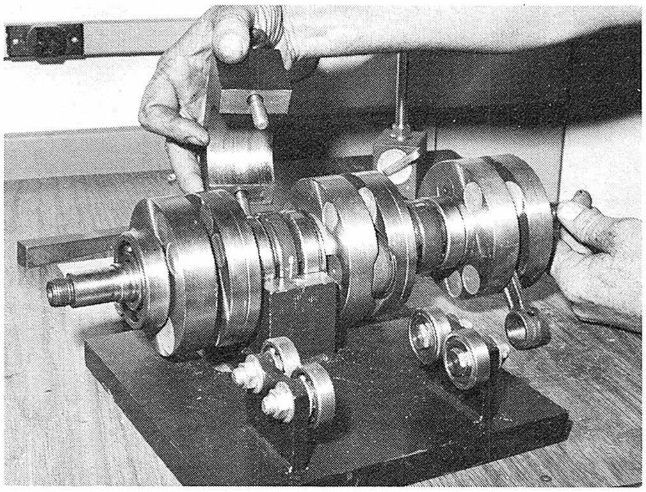
head should be milled by a competent machine shop to retrue it. An alternative is to replace cylinder and head.

Because of the soft metal used, threaded holes in the cylinder head or the crankcase can easily become damaged if care isn't taken. Normally, a tap can be used to clean away rust and excess metal or dirt. If the threads have been damaged beyond repair it is far simpler to drill an oversize hole and use a thread insert such as the "Heli-coil." The use of these inserts is especially helpful in the repair of damaged aluminum alloy case or head castings. The inserts are usually made of a strong steel. It should be remembered that *some* distortion and mismatching is standard practice where fastening two metal surfaces together. This mismatching helps keep the components from vibrating loose under excessive and hard usage. However, if the distortion is *too* great the threads could slip, causing damage to soft metal surfaces. To counteract this condition, it is advisable to countersink any hole that is to be threaded.

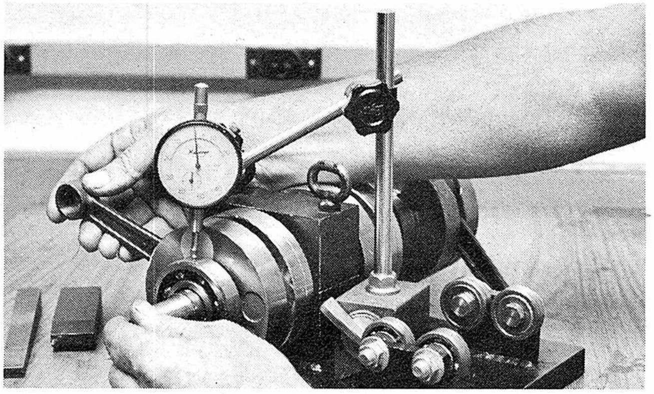
The greatest amount of wear usually found in an engine is in the cylinder bore, followed by crankshaft bearing surfaces. If the engine being repaired has many miles on it, a ridge will usually be formed at the top of the cylinder where the rings have reached the highest point of contact. This ridge can be removed by honing. Occasionally, the original pistons can



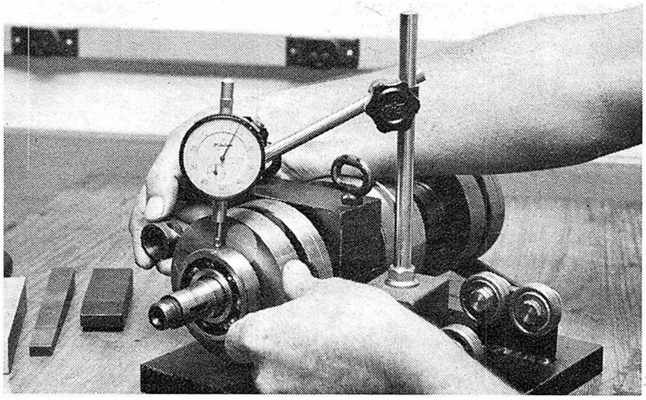
43. Inspect side of the rod surfaces and thrust washers. If old bearings or race are seized to rod, replace both.



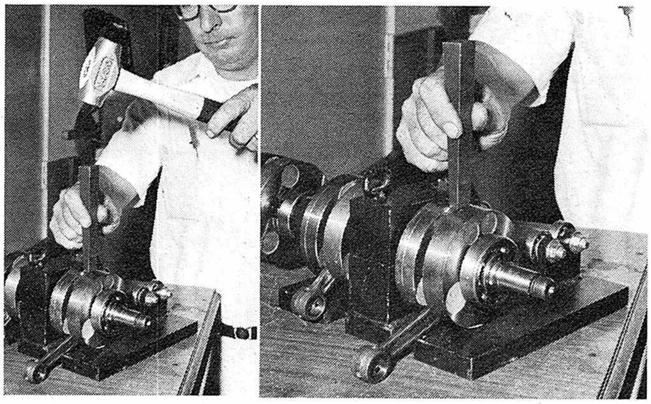
44. Most difficult of all cranks to reassemble is triple. Special jigs are required for cranks to measure runout.



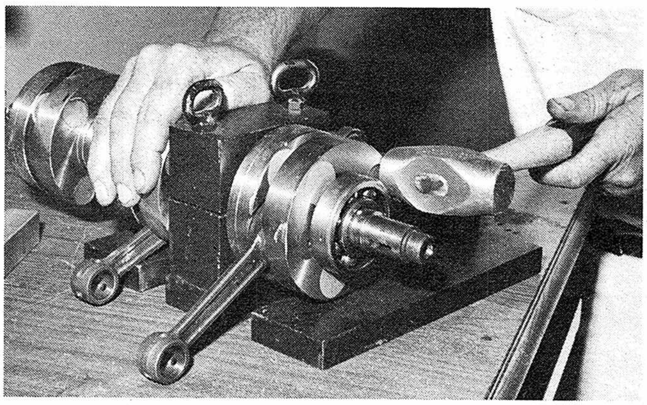
45. With the special crank jig, runout can be measured with dial indicator. Set D.I. at low spot of runout.



46. Spin the flywheels 180 degrees and the highspot is read. Preferably take the reading off the bearings, not crank end.



47. Using a wedge opposite the low spot, and with a gentle tap it will begin to straighten crankshaft alignment.



48. If the high spot is opposite the big end of the rod, a solid nudge with a brass mallet will do the trick.

be re-used in the rebuild job if new rings are used and if the cylinder has been honed. The honing operation also serves to remove any minor scratches and to give the new rings a good "bite" for reseating. It is best to check your set-up against the owner's manual to see that piston and cylinder clearance is not excessive. Unluckily, a piston pin may have slipped from the piston and cause considerable damage to the cylinder wall. If the cylinder wall cannot be bored to a larger size, then it is necessary to replace the cylinder liner. This operation is both time-consuming and critical, and could conceivably be really expensive. It is wise to check into the cost of purchasing a complete cylinder as well as into the advisability of replacing the liner. If piston seizure has been the problem it is best corrected by a minor honing job. The honing will remove the excess alloy material that has accumulated on the cylinder wall. Recently, some mechanics have found that a diluted solution of acid can be used to remove the alloy without damaging the cylinder wall. If acid is used to remove the alloy it is advisable to run the hone through the cylinder. This is to provide the new rings a suitable surface on which to run.

Boring the cylinder is relatively easy for an experienced mechanic. The cost is usually in the range of less

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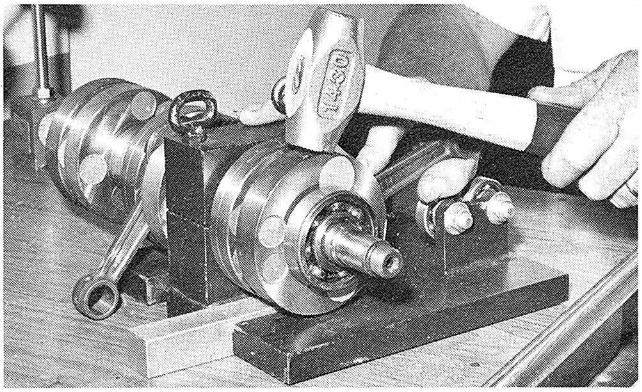
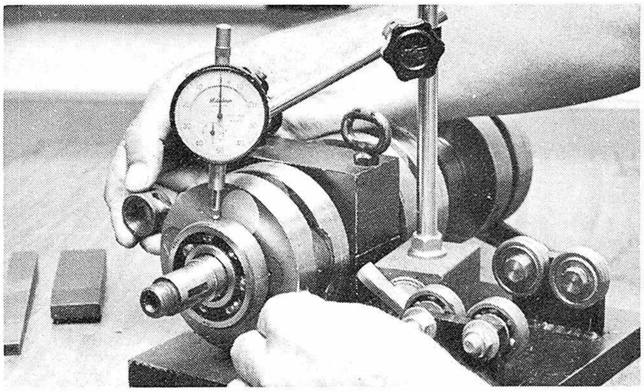
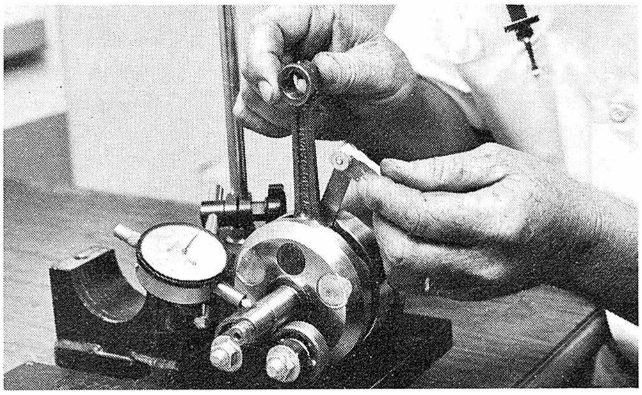


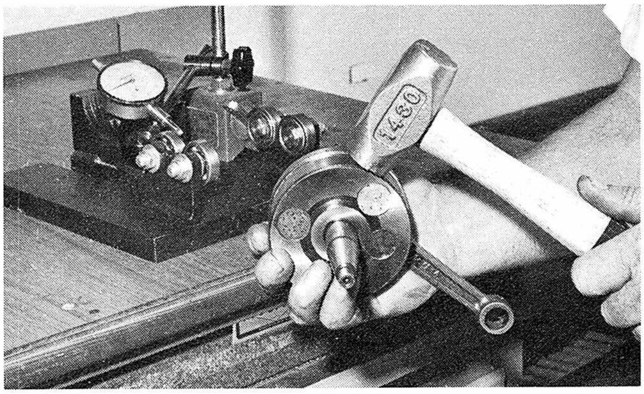
49. Also check horizontal flywheel alignment. Tapping the wheel(s) as shown on the high spot lines things up.



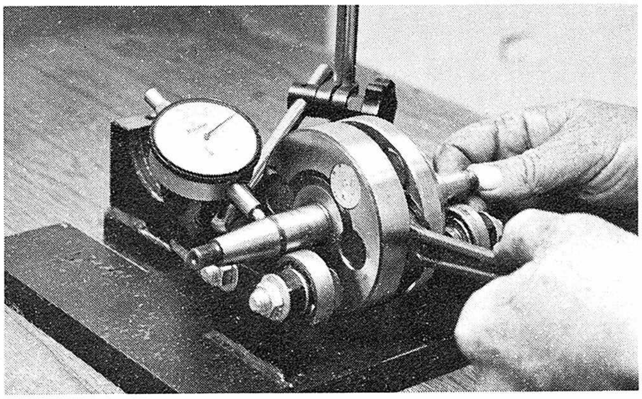
50. Check flywheel alignment in the same manner as runout. With twin and multi cranks, a specialist is worth the cost.



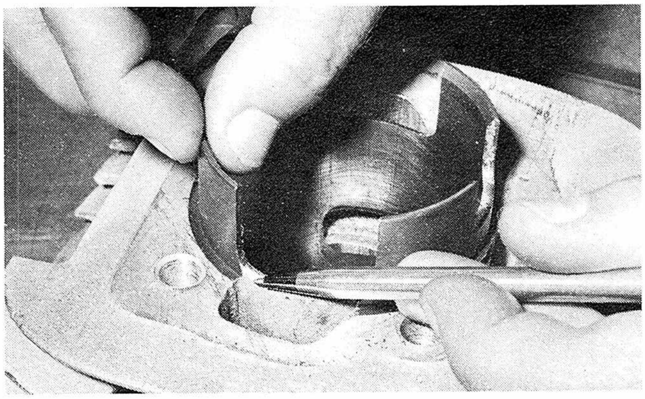
51. Single cylinder cranks are much easier. After pressing together first measure flywheel-to-rod clearance as shown.



52. Check for runout and flywheel alignment the same as with the multis. Always use a soft brass or lead hammer.



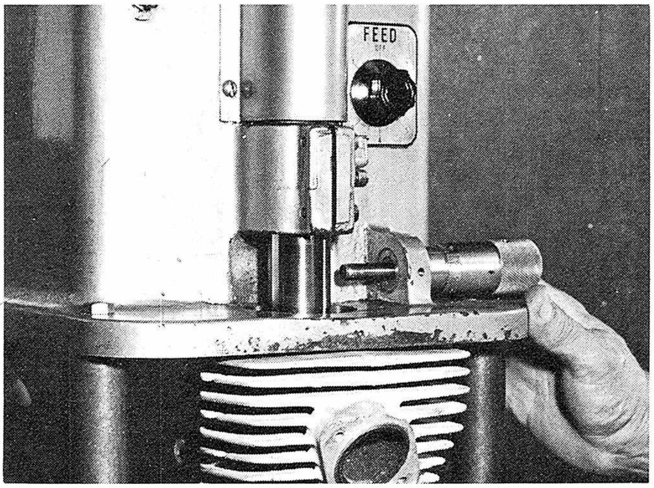
53. If desired, the runout may be checked without bearings installed. A drop of oil keeps D.I. from chattering.



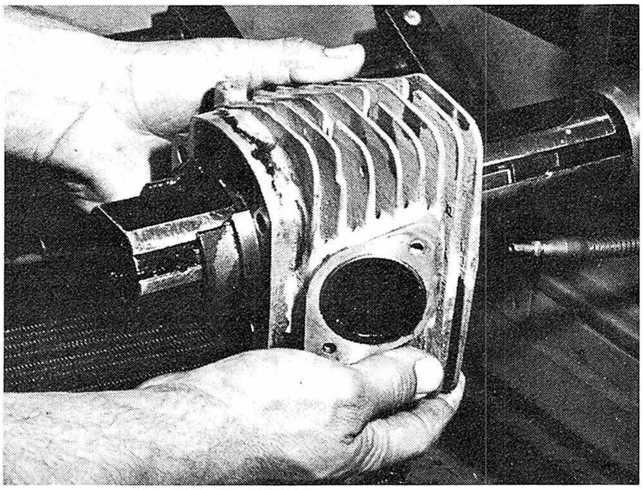
54. Always inspect to see if the steel sleeve has slipped up or down in the cylinder. Machine surface if necessary.

than $10.00 per cylinder. (A bargain when compared to the amount of work that it would take the amateur to do the same job) A cylinder should always be honed following any boring operation. This is done to bring the cylinder to a final correct diameter. The proper surface for a cylinder wall is not extremely smooth. The rings will not seat if the walls are initially too smooth—compression blowby will surely result. Also, a too-smooth cylinder may get scored from lack of lubrication. The cylinder wall should feel smooth to the touch and will look like it has a satin finish with cross-hatch patterns. If done by a professional the honing operation is usually included in any rebore job. Following the boring job it may be necessary to chamfer the lower edges of the cylinder bore to facilitate the replacing of the rings.

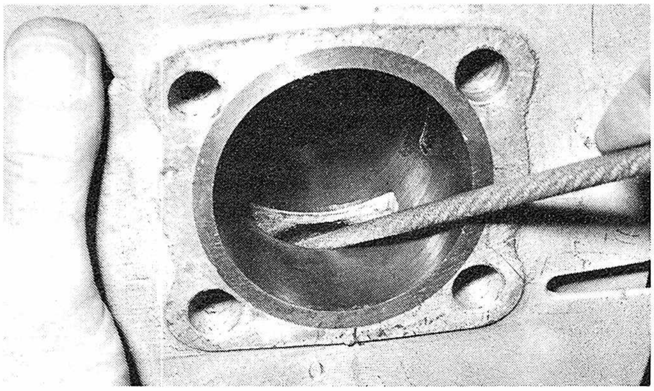
Generally speaking, crankshaft bearings will outlast pistons and rings several times over, so replacement may not be necessary. Roller bearings in the rod big-end will permit the rod to rock sideways to a slight degree, therefore there must be some side clearance. But with the rod held firmly to one side, gripped near the bottom, there should be no perceivable up and down play. The ball main bearings should turn freely with no side play and be virtually silent if oiled. Checking of crank bearing condition is something that should be left to the professional if replacement is re-



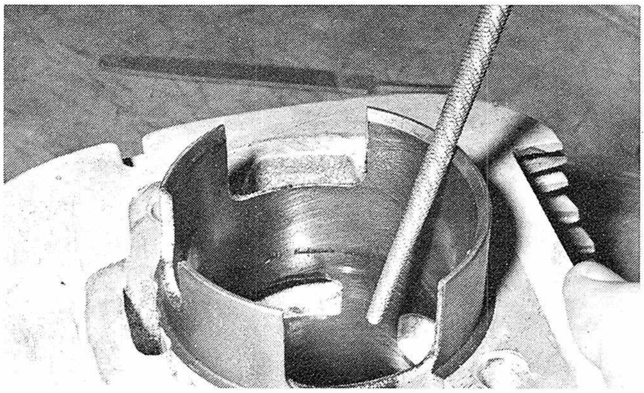
55. Well equipped dealers will have professional boring bars. Cost for one size over should be $5.00 to $10.00.



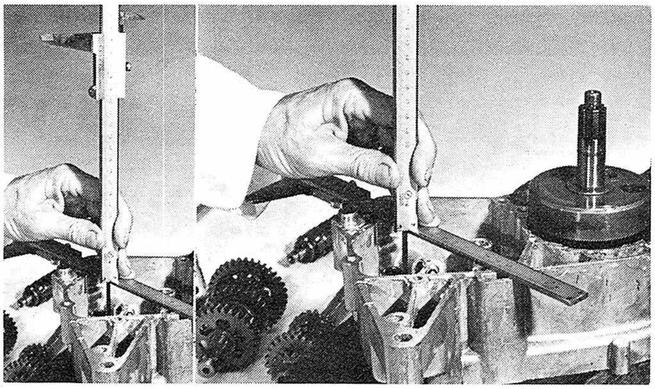
56. Be sure the steel liner is honed if a boring bar is used to ream out the sleeve. Boring leaves rough surface.



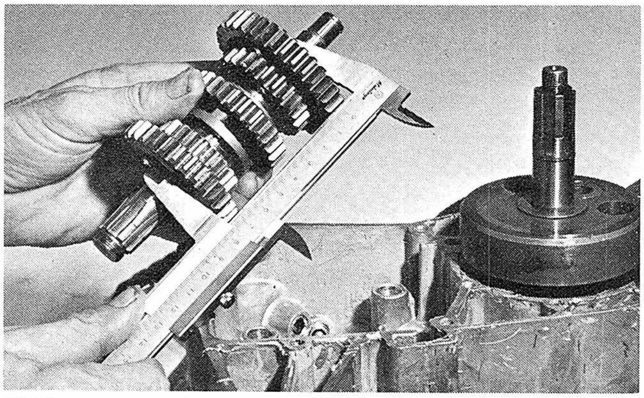
57. Use a fine rat tail file to chamfer the horizontal port edges. A sharp edge will break the piston rings.



58. Repeat the chamfering process wherever there's sharp edges. Wash cylinder in soap and water before replacing.



59. Before reinstalling the transmission, especially Japanese, measure case width for gear assembly shimming.



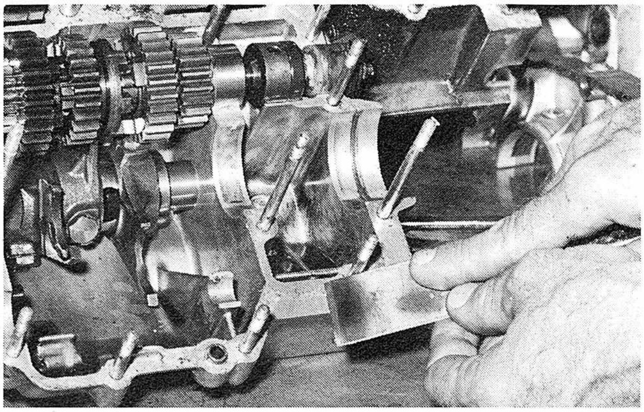
60. Now measure the gear assemblies and subtract the difference. End play shouldn't exceed .005- to .007-inch.

quired, the pro's equipment and facilities will afford the best job. "Splitting the cases" often requires special tools; replacing the rod big-end bearing means pushing the crank pin out of the flywheels with a hydraulic press. When reassembling the crank you will need a special fixture for a dial indicator alignment check of the main shaft sections.

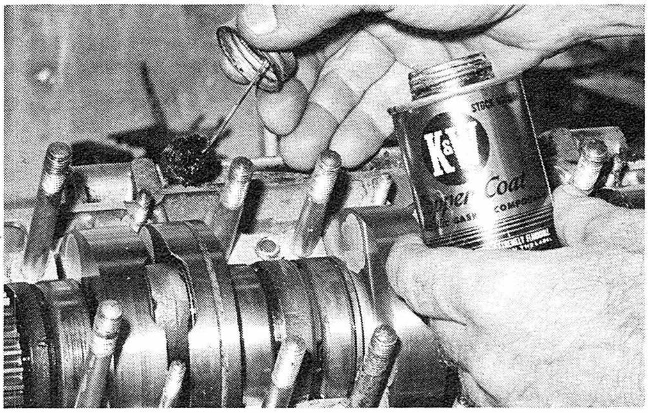
Connecting rods themselves rarely suffer any damage unless there has been piston seizure, extensive breakage, or the engine has had super-hard use. If the rod is removed for crank bearing replacement it should be examined to see if any bending has taken place. Straightening of two-stroke rods *can* be done, but generally their unit cost is low enough to justify replacement for safety's sake.

Just as important as the "hard parts" in a two-stroke are the "soft" seals and gaskets. A leaky crankcase in a four-stroke will leave a puddle on the garage floor, but in a two-stroke it can effect engine operation to some degree, even to the point of repeating any damage which may have required the overhaul. Crankshaft seals should be replaced any time an engine is

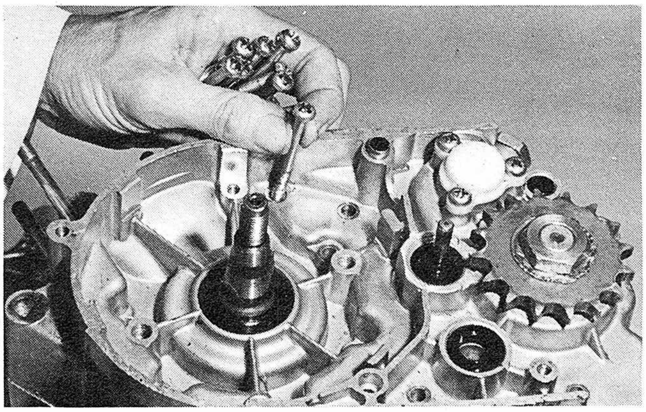
HOW TO: Overhaul Your Two-Stroke



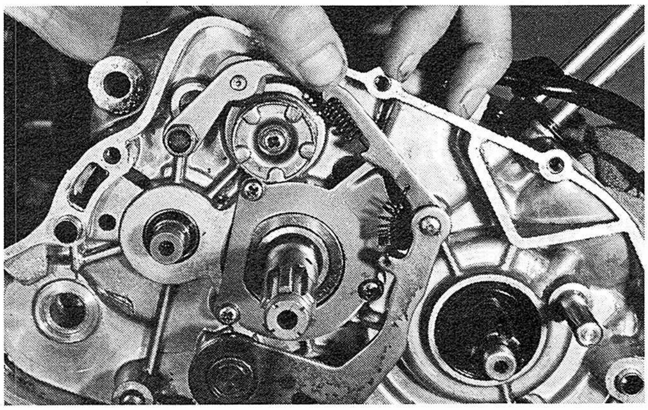
61. Clean the crankcase surfaces with putty knife and solvent before assembly. Don't scratch or gouge surface.



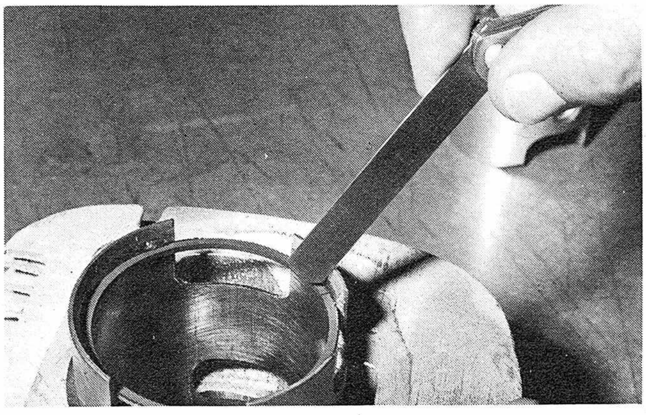
62. Always apply a good motorcycle gasket sealer before placing case halves together. Keep it out of innards.



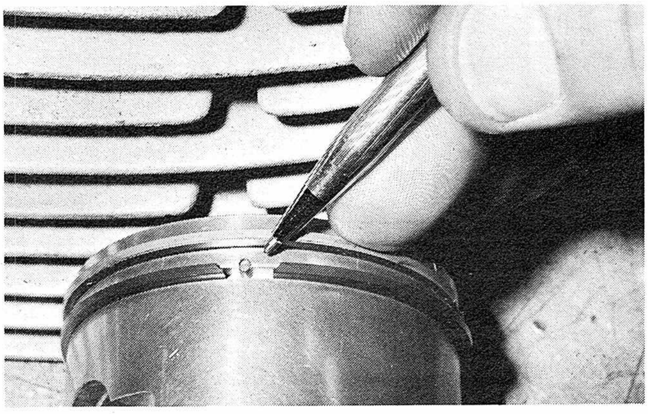
63. Clean all the hardware before reinstalling. Use only impact driver or torque wrench on screws and bolts.



64. If you didn't move the shift linkage eccentric screw, everything should line up without readjustment.



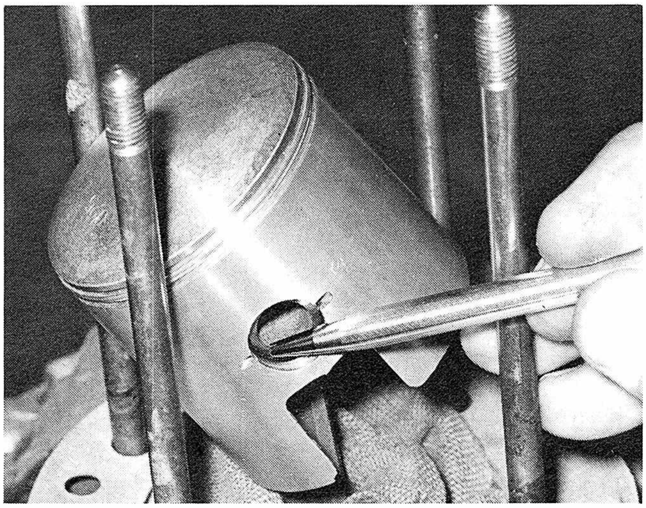
65. Measure ring end gap with feeler gauge. File ends until correct factory recommended clearance is obtained.



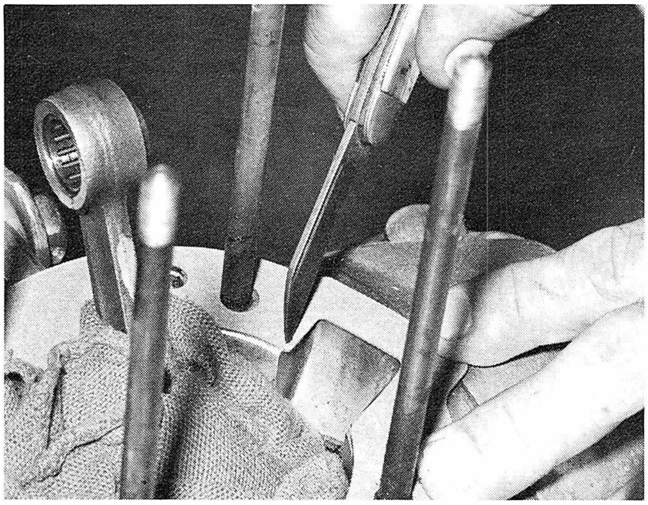
66. Make double-sure the rings are right side up and match up with locating pins in piston. Lightly oil rings.

dismantled, and the seal running surfaces should be carefully checked for wear. Mating surfaces of the crankcase halves should be checked for cracks and nicks and thoroughly cleaned prior to assembly. Most crankcase joints do not use gaskets, but sealants such as Yamaha Bond No. 5 or Permatex are a must to insure proper sealing. Cylinder base gaskets and other paper gaskets are "best held in place."—their sealing will be assured by using a rubber cement such as Gasgacinch.

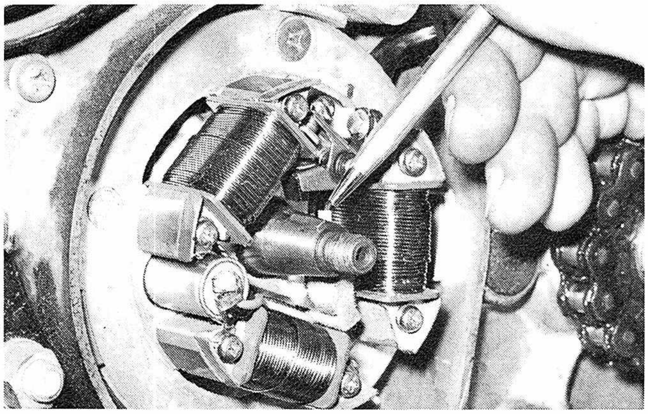
So there it is in a nutshell. The simplicity of a two-stroke makes it easy to overhaul on paper, but the work itself is something else. Study that service manual carefully and don't hesitate to call on your dealer for help. Remember, patience and neatness are your best assets in the garage. While you're at it, you may be interested in doing a little super-tuning on your engine so have a look at the chapters on "More Power" and "Two-stroke Hop-up." Refer to the chapters on carburetion, electrical, and tune-up for tips on keeping your bike in top running condition. In addition to saving some money, doing your own work can both be fun and a lot of satisfaction. So Enjoy!



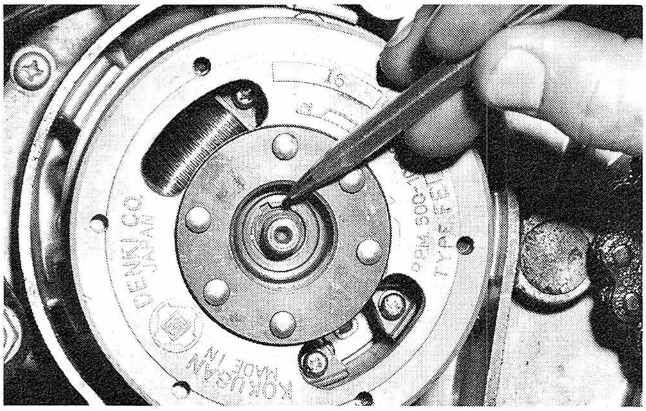
67. When replacing the wrist pin circlip be triple-sure it fits in its groove. Spin with needle-nose pliers.



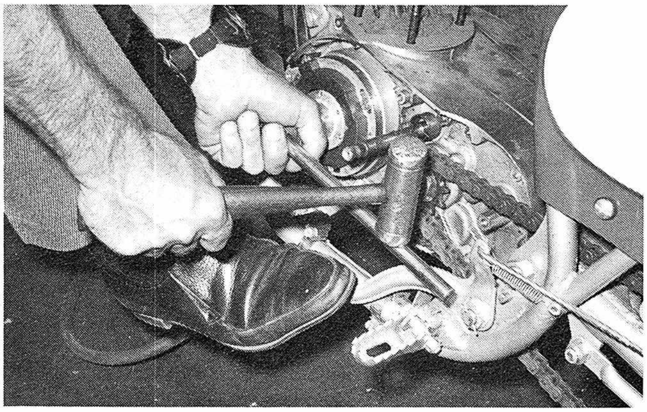
68. If the cylinder base gasket is a bit large inside, cut it to fit ports and sleeve with a sharp pocket knife.



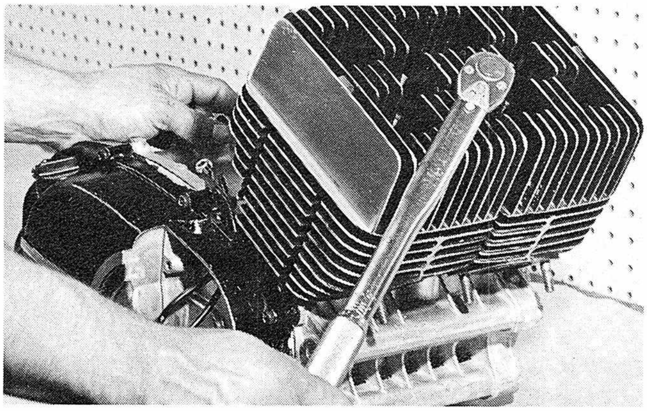
69. Place woodruff key with outer edge slightly up to ease flywheel installation. Some engines need Loctite on shaft.



70. Don't force the flywheel on a tapered shaft. It should fit smoothly. Sharp tap with hammer will seal on taper.



71. Get that flywheel nut on tight. To insure it staying in place Loctite on the nut is a good idea for insurance.



72. Not enough can be said about following torque specs. Proper tightening will insure good sealing and no leaks.

LUBRICATION: 2 STROKE & 4 STROKE

Regardless of what type of machine you own, its life depends on the correct use of the proper lubricants

BY PEPE ESTRADA

Few subjects have been so ignored in motorcycle publications as the ones we'll discuss in this article. Friction and lubrication is a universal subject. There is no part of the earth that is free of it. There is very little that man does to which it doesn't apply. Every area of mechanics relies on friction. Every machine needs lubrication. But for some reason this subject has been taboo for writers who treat other motorcycle subjects.

Physics is another subject that has been ignored, but rightly so, because physics and mathematics are beyond the scope of motorcycle publications, as is chemistry. We're going to treat the subject of friction and lubrication in a common-sense, useful way. Did you know that the highest possible friction between metals always occurs between two *highly polished* metal surfaces rubbing together? Did you know that friction between metal surfaces will be *reduced* if the surfaces are roughened up slightly? But not too rough. Did you know that surface friction is *lower* with a thick oil than with a thin oil? Did you know that friction *decreases* with faster speeds? That is to say, there is less friction at a high speed than at a low speed. Did you know that friction is a process of converting mechanical energy into heat energy? Did you know that high friction between metal surfaces is very similar to a welding process? Did you know the difference between the *real area* of contact and the apparent area of contact? When you look, for example, at one flat metal on another flat piece of metal the real area of contact between the two is actually but a tiny portion of the apparent area because only the high spots of one side touch only the high spots of the other side across the interface. These tiny spots of real contact are called junctions which join together in plastic formations that resist motion between the two surfaces.

The modern study of friction is barely 20 years old. It started in earnest during World War 2 when answers had to be known because of the urgency of the world situation at the time. We were fighting a war. Practical solutions, not classroom answers were needed. Ancient ideas have been modified and modernized in the past 20 years. Also, radioactivity has proved a valuable tool in determining the wear of materials. For example, radioactive pieces are assembled and then run. The highest resulting contamination of an oil will be with radioactive particles from the parts that are wearing the most.

GOOD OILS

Electron microscopes have come a long way in the last 20 years. Some 100,000 magnifications are now possible. It's important to be able to see what metal surfaces really look like up close—real close. Good oils and greases yield better looking surfaces after service. Poor lubricants can actually destroy rubbing surfaces in seconds.

It's not exactly easy to design a good oil. There are many steps along the way. Many oil additives are touchy since you're dealing with chemicals that prefer only certain combinations for best results. In this respect, an oil designer is like a superb chef (or should be).

Oils are classified four ways: Mineral, vegetable, animal and synthetic. Mineral oils are derived from petroleum crudes. Technically, these petroleum products fall in a category of chemicals called the saturated aliphatic hydrocarbons. The crude is refined by several methods into many divisions of light and heavy liquids. The light ends boil easily and become fuel fractions, while the heavy ends become lubricating oil and tar fractions. Ordinary pump gasoline is about 90 percent fuel, leaving 10 percent residual oils and heavy ends. The oil in gasoline serves to lubricate the upper walls, rings, and intake valves. A straight mineral oil is usually a high purity paraffin with no additives.

Vegetable oils are derived from present day plants. Examples are soybean oil and castor oil. Castor oil is often used because it forms a strong film on iron and steel surfaces. It also does not thin out too drastically at 210°F. However, it oxidizes badly

1

and often doesn't like blending with other oils. It seems modern day petroleum oils have put castor-based oils in the old rumble seat. Animal oils are quite useful, especially in gear lubes. Sperm oil has excellent anti-wear and high EP (Extreme Pressure) properties. It is used in most limited-slip differential lubricants. In fact, new applications for deodorized sperm oil are still being found. Does that sound fishy?

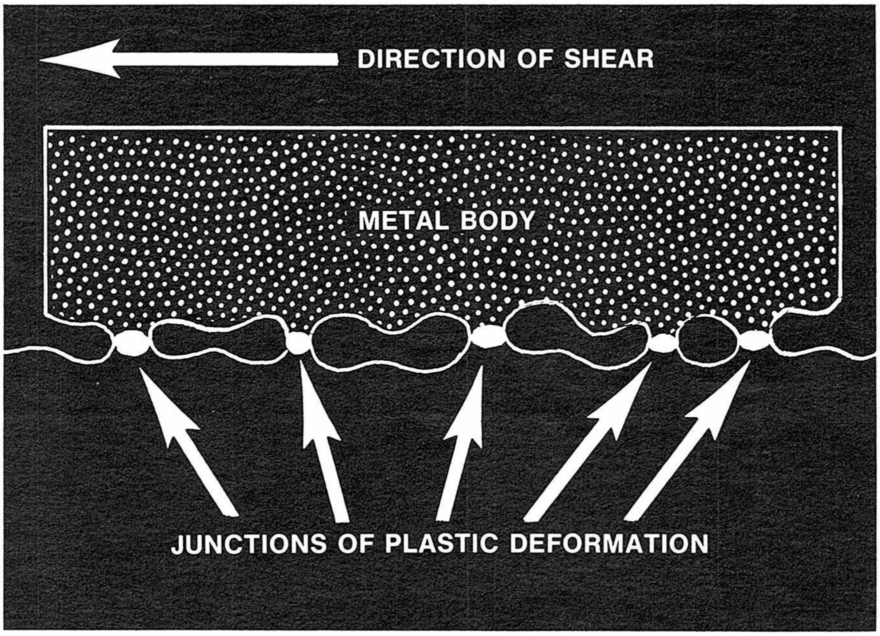
Synthetic oil is man-made. It is usually Polyalkylene Glycol based. Its chemistry is such that it is not highly reactive. This means synthetic oil does not easily oxidize, form sludge or leave carbon deposits. On the other hand, these oils lack EP resistance, form no absorbed film and exhibit only medium anti-wear properties. However synthetic oil is excellent in cosmetics, hydraulics, and as special solvents. Some synthetic oil compounds are advertised as being "non-greasy" or "dry," as opposed to "greasy kid stuff" which uses petroleum oil or jelly.

Some two-cycle engine oils are of the synthetic variety. There are practically no combustion chamber deposits. The exhaust is clean also. However, you should run about 13.0:1 premix ratio and open up the jets a little if you plan any hard running with these oils. For the remainder of this article, we'll be referring strictly to mineral oils because they make up 99 percent of all the oil sold in the world. So let's take a look at some of the properties of mineral oils.

VISCOSITY

By viscosity we mean the rate at which a fluid will pass through an orifice. The word viscosity when applied to oils has several synonyms: grade, weight and thickness. They mean about the same thing. A grade is a specific range of oil viscosity between certain temperature limits. For example, the viscosity of 30 weight motor oil must fit definite specifications at 0°F, at 100°F, and at 210°F in order to be called 30 weight motor oil. These rigid specifications are actually state laws in most of the U.S. However, 80 weight oil could very easily be called a 30 weight oil because the two viscosity specifications are quite similar. The big difference in the two is the additive package of each oil. The 30 weight is designed for engines. The 80 weight is designed exclusively for gear boxes. A 75 weight gear oil has about the same viscosity range as 10 weight motor oil. So don't let the numbers fool you. Gear oil viscosity specs are on a different scale than the motor oils. In motorcycle gear boxes we strongly recommend you use 80 weight gear oil rather than motor oil.

The load carrying ability of any oil is directly affected by the viscosity. A thin oil cannot resist high loads as well as a thick oil. For this reason it's vitally important to possess sufficiently high viscosity at high temperatures when an oil needs all the help it can have. A multigrade oil is one that fits the viscosity range of a light weight at 0°F but also fits the range of a heavy weight oil at 210°F. Such oils are very good in winter climates. Viscosity is an oil's best friend. Without it, oils would be squeezed out immediately and vaporized by high frictional heats. However, it does no good to have more viscosity than we need. Proper viscosity depends on loads and temperatures of the job.



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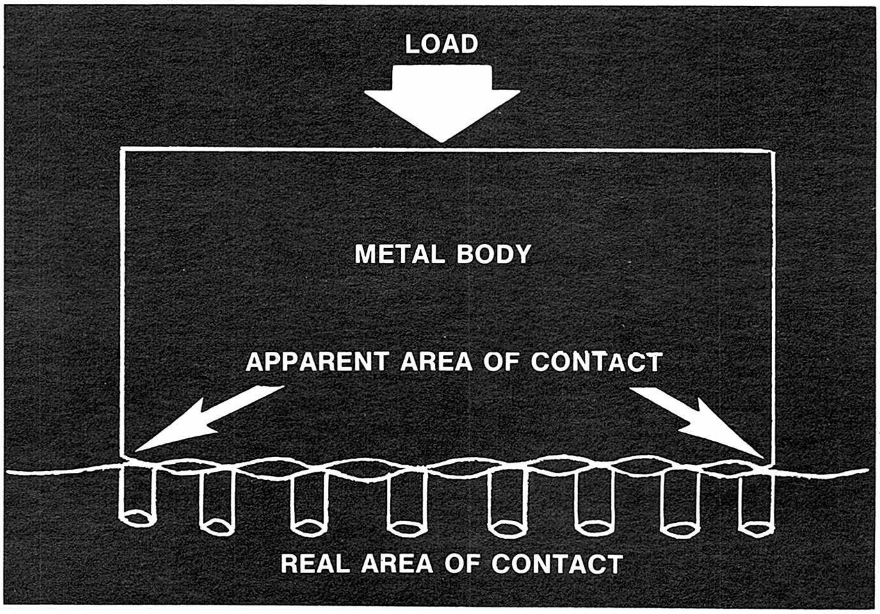

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1. There is a reason for all of the different types of oils. Each one is best for its intended job.

2. Schematic of a metal body sliding on a metal surface. Only parts in contact are high spots (called junctions), which join like pieces of clay. As the body moves, junctions are broken and reformed. Friction heat is created at these tiny, but numerous high spots.

3. A microscope reveals that the real area of contact is a small percentage of the apparent area between two pieces of metal. The real area increases as smoothness of surfaces is improved. A polished surface would have the most real area of contact.

LUBRICATION

RANGES OF SAE STANDARD SUS VISCOSITY

WT.	ZERO°F.	100°F.	210°F	
5W	4000 MAX.			Winter-grade motor oils
10W	6000-12,000		35 MIN.	
20W	12,000-48,000		40 MIN.	
10	6000-48,000	150-270	40-45	Motor Oils
20	48,000-85,000	270-400	45-58	
30	85,000-125,000	400-700	58-70	
40	125,000-250,000	700-900	70-85	
50	250,000 MIN.	900-1600	85-110	
60		1600-2100	110-130	
70		2100-4000	130 MIN.	
5W-20	4000 MAX.		45-58	Multi-grade motor oils
10W-30	12,000 MAX.		58-70	
20-20W	48,000 MAX.		45-58	
20-40	85,000 MAX.		70-85	
75	15,000 MAX.		40-48	Gear oils
80	100,000 MIN.	400-800	48-75	
90	200,000 MIN.	800-1500	75-120	
140		1500-4000	120-200	
250		4000 MIN.	200 MIN.	
80-90	200,000 MAX.		75-120	Multi-grade gear oils
90-140	300,000 MAX.		120-200	

COURTESY OF VALVOLINE OIL COMPANY

SUS AT OIL TEMPERATURE

WT.	60°F.	90°F.	120°F.	150°F.	180°F.	210°F.	240°F.
10	700-1400	220-390	100-160	60-82	47-57	40-45	36-39
20	1400-1700	390-600	160-250	82-130	57-80	45-58	39-48
30	1700-3000	600-900	250-400	130-180	80-110	58-70	48-55
40	3000-4500	900-1500	400-500	180-250	110-130	70-85	55-63
50	4500-8000	1500-2500	500-800	250-370	130-200	85-110	63-77
60	8000-13,000	2500-3000	800-1000	370-450	200-240	110-130	77-90
70	13,000-40,000	3000-7000	1000-2000	450-750	240-300	130-140	90-95

Oil companies keep a close eye on the viscosity of their oils. This is done in a saybolt bath which is a small tank containing warm mineral oil. The bath is precisely regulated at 100°F or 210°F. A sample oil to be tested (about one ounce) is put in a small graduated curved glass container. This container is then placed in the bath and allowed to warm up to the bath temperature. When it does warm up, the curved container is tipped over so the oil specimen inside flows from one end of the tube to another. The seconds are counted that it takes the oil sample to flow between graduations. At 100°F, a 40 weight motor oil must take 700 to 900 seconds to flow between graduations. Sound like a lot? Well at 210°F the same 40 weight oil takes only 70 to 85 seconds. Each of these seconds is an SUS or saybolt universal second.

Can you appreciate that viscosity drops radically due to elevated oil temperatures? The viscosity of water, if tested in a saybolt bath would take only about 15 SUS at room temperature. That's mighty thin. We've included SUS charts for you to check out oils of various weights. Notice that 90 weight gear oil is similar in viscosity to a heavy 40 weight motor oil. Also that a heavy 20 weight oil is nearly a light 30 weight or that a heavy 50 weight is almost like a light 60 weight oil. Weights range from 5W (5 weight wintergrade) all the way to 250 weight for the thickest tropical-grade gear lube. Oils come in many colors and grades. At a mixing station you can see how the various stocks, as they're called, are combined to produce some desired oil ready to be packaged or canned.

To start with, bright stock is a refined paraffin oil of about 150 weight. The best bright stocks are the purest (generically) and naturally most expensive. Neutral stock is a highly refined oil of about 5 weight viscosity. Again, the best neutral stocks are the purest. Mixing neutral and bright stocks together yields base oil stocks that will become our many motor oils and gear lubes. A 60 weight racing oil is mostly bright stock. A 20 weight oil has mostly neutral stock in it.

Then comes the additive package. What do we want? A gear lube? OK, such a package could contain sulfates, chlorinated stocks, phosphates, and lead stock. But an additive package for a motor oil would never contain sulfates or chlorinated hydrocarbons. Such chemicals would damage an internal combustion engine. However, diesel engine oil packages must contain silicones for anti-foam, oxidation retardants, anti-rust, *zinc-phosphates,* and *polymers.*

Polymer stock is a terribly "gooey" substance. A polymerized oil takes less bright stock and more neutral to achieve the same weight oil. But there are several important differences. A polymerized oil is not so thick at lower temperatures. That's good because it tends to retain viscosity at high temperatures. That's very good. But it may oxidize at a high rate which is very bad. Polymerized oils require special additive packages to offset the oxidation problem. Multigrade oils lose thickness sooner than non-polymerized oils. In other words if you use a 10/30 weight oil for 500 miles then test the SUS viscosity, you'll find it has dropped to perhaps a 10/20 weight. This drop is due to repeated shearing of the polymer stock. Of course, all oils tend to drop viscosity with normal use but multigrades drop a bit more. The way to fight this characteristic is in careful selection of base stocks, expressly for multigrade use. Remember the meaning of the word paraffin: "slight affinity." Polymerization raises the activity of hydrocarbons. If an oil is over-polymerized by an inexperienced individual, it cannot tolerate high temperature operation because of the resulting oxidation.

Oxidation is slow death to lubricating oils. When our pure hydrocarbon molecule picks up an oxygen molecule it ceases to be a lubricant. It becomes a particle of sludge or tar. Whatever it becomes—it is no longer useful as an oil. Prolonged oxidation of a lubricant produces real abrasives besides the sludge, gums, acids, jelly, and tars. Oxidation products are called carbines, carboids, and carbides. Carbines are fully soluble in oil

and account for the dark color of oils after use. Carboids are only partially soluble and fall out of oil when it's cold or inactive. Carbides are fully insoluble and form sludge deposits in the bottom of the crankcase and in crevices. As you might guess, carbides are abrasive. All of these products are the result of heat, oxidation and time. If the oil is changed frequently, along with the filter, the carbines and carboids would be removed before they can progress into carbides. But drain the oil hot, not cold. Don't go more than the recommended miles between changes; we don't care what the salesman told you. He wanted to sell that machine, and his boss wants you to bring it back for repairs and buy another motorcycle from them in a few years. Believe it!

If an oil is heated past about 150°F, the rate of oxidation doubles for each succeeding 15 degree rise in temperature. And if the oil is agitated with hot air (as in the crankcase), the rate nearly doubles again. We state most emphatically: The worst damage to an oil is entirely due to heat and infrequent oil changes. What we're coming to is this—buy a good oil and use it for what it was intended. Follow the manufacturer's advice. Don't mess around with it by adding anything unless you are a lubricants engineer and being paid for it. There is absolutely nothing you can do to improve a good oil. You can only lower its load carrying ability by playing with it. A good polymerized oil is a tricky thing to perfect. Fortunately we have some pretty good oilmen in this country. So our modern oils really have it. They flow freely at moderate temperatures without losing it at 210°F. They last for long periods of time or for several thousand miles of stop-and-go-traffic.

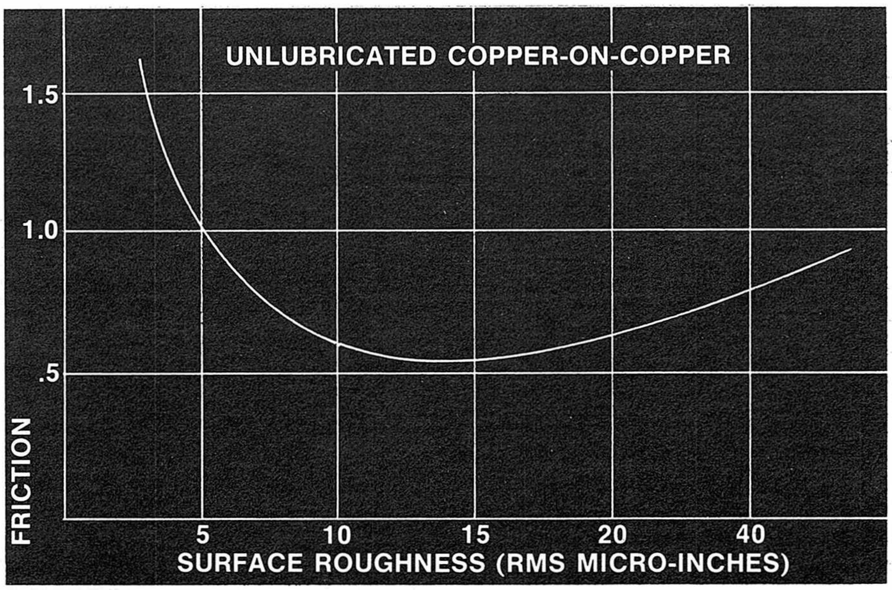
We should add that cold oil is quite dangerous if you were a motor. You see, cold oil is sluggish, like glue. One cold start is harder on an engine than many hours of running. Imagine the oil pump trying to draw that cold oil out of the sump. Only as much oil can enter the pump as atmospheric pressure can force into the intake side! For this reason *never* rev a cold engine. Take it easy until it's up to temperature. If the pump is turning too fast for the oil viscosity, then cavitation occurs. The oil will foam. Instead of sending liquid lubricant to the bearings, you'll pump mostly oil vapor.

ADDITIVES

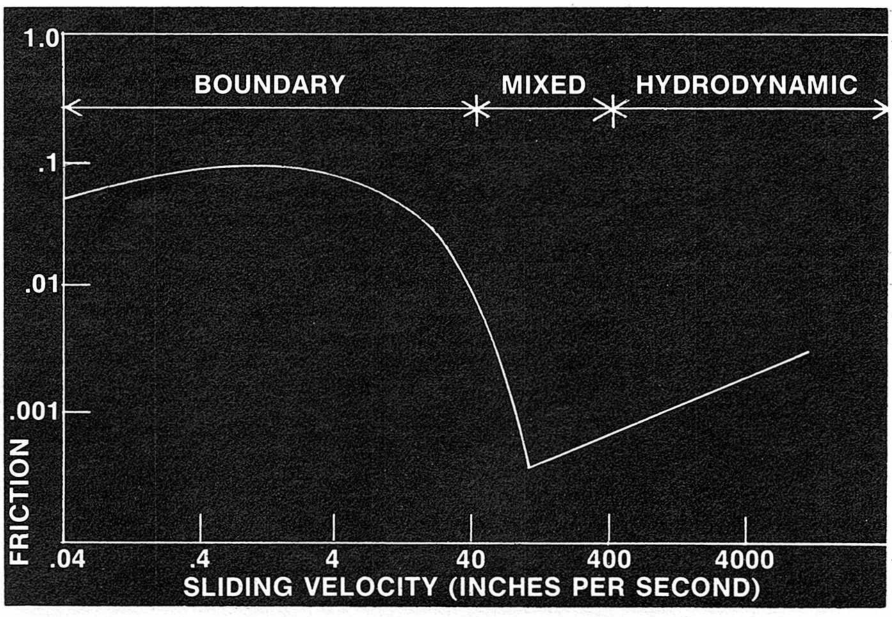
Detergent or non-detergent? That is the question. All good oils must contain ZDP. That's the same ingredient that at once aids detergency and load carrying ability. We cannot do without some detergency. Some so-called non-detergent oils are actually "low-detergent" oils sold at a lower price. Some lucky Texas oils were phosphated by mother nature and stored underground for our use. They are sold as non-detergent only because little or nothing has been added. Such an oil bears no label on the can, just a plain top. But avoid the impression that all unlabeled oils are good. They are mostly not. A better word for detergency is dispersency.

The way dispersency operates is to raise the solvency of the oil and keep sludge particles such as carbines in solution and carboids in suspension. Some of the dispersent additives are Barium and Calcium sulfonates and alkylpolyamides.

The two ways that load carrying additives operate is through active film adhesion or through a heat seeking chemistry. Chlorides and sulfides are of the former type. They develop very strong films on metal surfaces. Metallic phosphates are of the second type because these fantastic mole-



1. Graph showing friction difference between flat polished surfaces and rough surfaces. Friction level is lowest between 10 RMS and 30 RMS. Steel and other metals exhibit test results similar to this graph of copper.



2. This is the relationship between sliding speeds and friction. Boundary conditions are due to more junctions being formed at low speeds. As speed picks up there is a hydroplane effect which causes separation of rubbing surfaces.

cules automatically find the hot spots of actual contact or junctions and form a flux on them like a soft powder. This flux formation is much softer than the parent metal and so it begins to dissolve into the oil as rubbing friction continues. That's good. Phosphates are such good heat seekers that all good oils contain them. Yes, and even good gasoline too. It's a good cleaner as well as an upper cylinder lubricant. If it weren't for EP additives, the junctions would break as rather large debris particles and cause scoring.

SPECIAL USE OILS

The labels ML, MM, MS, DG, DM and DS appear on the tops of oil cans. What do they mean? In order, the initials represent: motor light, motor moderate, motor severe, diesel general, diesel moderate, and diesel severe. The labels also indicate what general type of additive package is in the oil. ML oil has a light package while DS carries a complex package of anti-foam, EP, dispersent, polymers, anti-wear, rust inhibitors, corrosion and oxidation inhibitors.

There should be a special class of additives used only in two-cycle engine operation. This is because of the special difficult conditions of two-cycle operation. The worst possible thing you could do to a two-cycle engine is use an automotive oil intended for four-cycle engines! No such oil can cope with the heat and deposit problems of any two-cycle. We'll discuss these problems at length.

Soon, if the present trend towards rotary engines continues, we'll be seeing special oils compounded to better fight the particular lubrication problems of rotary engines alone. Along these same lines, you cannot use gear oils in any kind of engine. They would be extremely corrosive to pistons and bearings. Furthermore, gear oils lack some of the ingredients needed to protect against combustion products. Nor should engine oil be used in gearboxes or motorcycle forks. Engine oils are low in high temperature phosphates and have no sulfides that gears thrive on. Generally gear oils need high EP chemicals not in motor oils.

Fork oil is a mixture of paraffin and napthene oils to protect and control seal expansion. It also needs anti-foam and other special additives not

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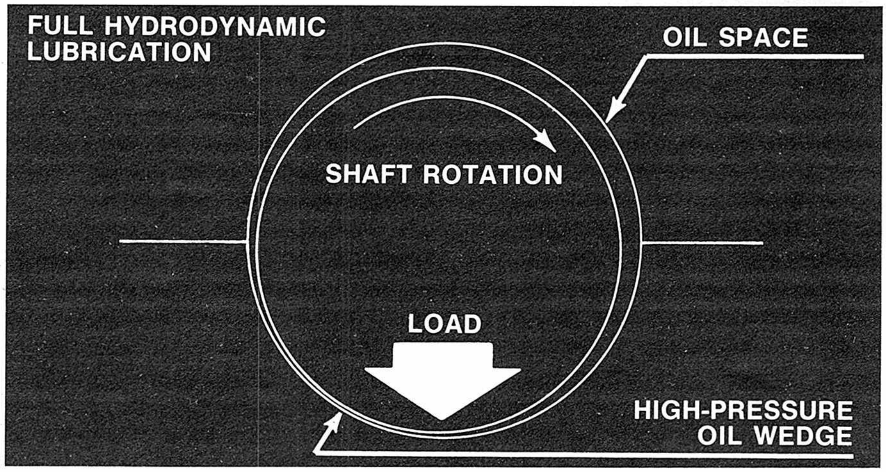

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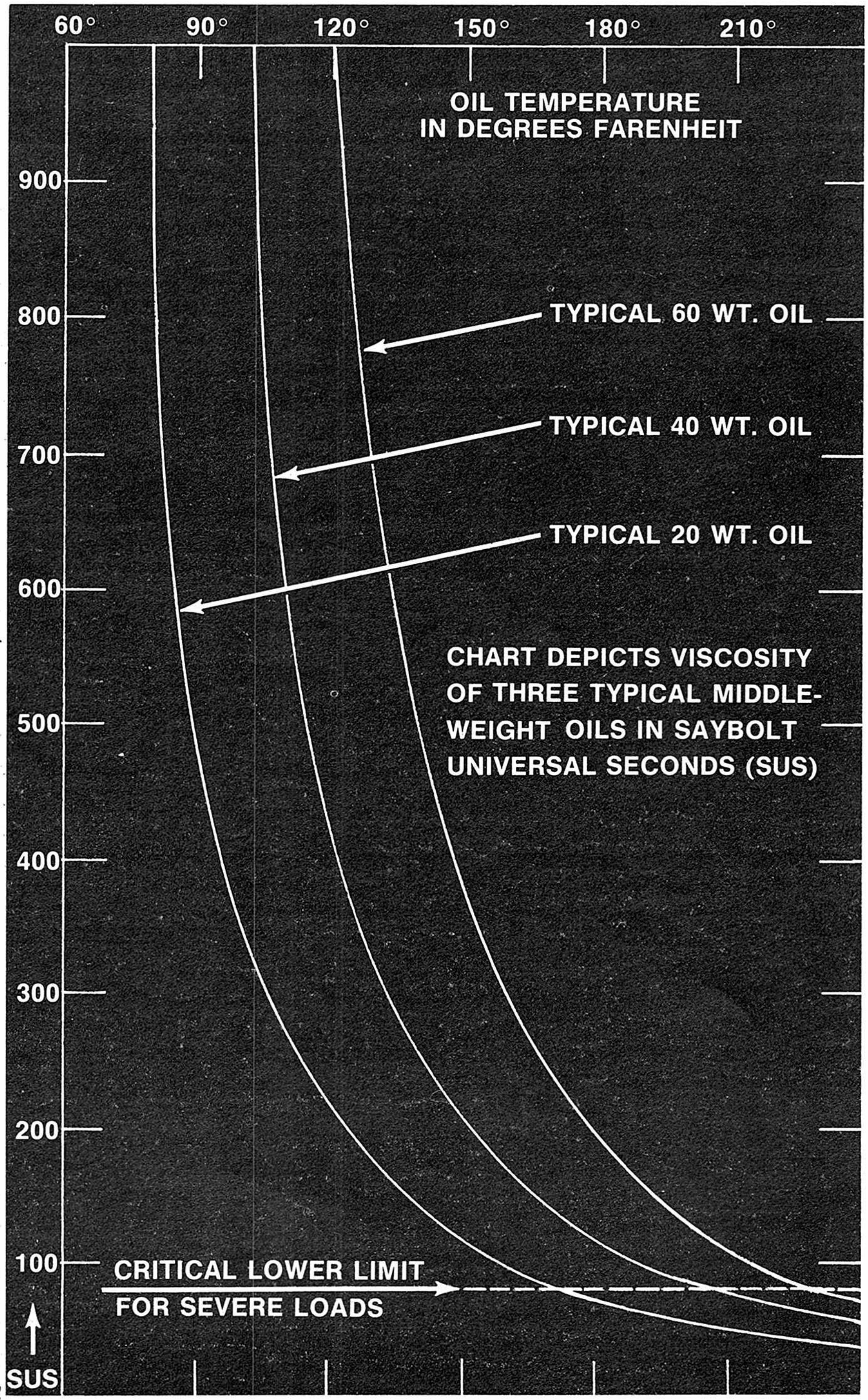

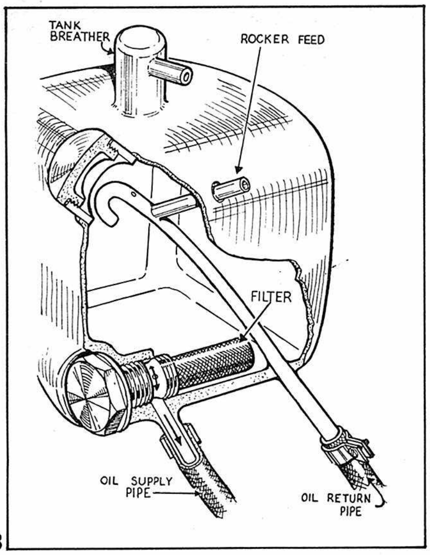

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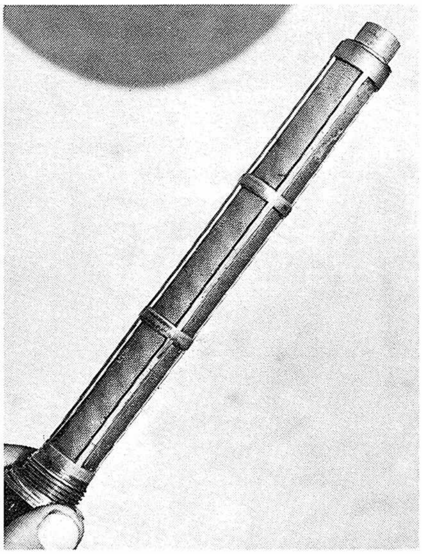
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1. The lower left section of the shaft doesn't actually touch the bearing, thanks to a high pressure oil wedge that is constantly being drawn between the shaft and the bearing.

2. Graph showing viscosity losses due to heat. Thickness of oil is determined by its use and how hot it is going to get. Thicker oil is best for heavy duty or racing because of higher viscosity at temperature. Multi-grade oils contain polymerized stock to be thinner when cold, thicker when hot.

3. There is also a screen on the crankcase drain of these dry-sump oil systems. It should be cleaned at every oil change.

4. Screens like this (from a Ducati) are found on most Hondas too. They keep unwanted "junctions" from forming in the engine.

found in motor oils. Motor oils are not all the same, are they? So a poor motor oil could well ruin an expensive set of forks. What's a good motor oil? Only your chemist knows for sure.

It should be clear by now that of all the oil stocks and available additives around that many of them are not compatible when mixed together. That is, the result is a poor lubricant, if indeed you could call it that. And it doesn't take much to turn a good oil sour, sometimes as little as a few drops can do it. Never mix oils yourself. Never combine oils of different labels, even if they're made by the same company. Throw away a used filter. It's an obvious contaminant.

Racing oils are a special breed. If properly blended, the very best stocks went into their manufacture and rigorous laboratory testing is conducted to guarantee quality control of the end product. It's normal for racing oils to have a different (less complex) chemistry than street motor oils. The emphasis in a race oil is on EP, oxidation resistance, high temperature viscosity, anti-foam, and compatibility with nitrated fuel. Did you know most oils form an explosive mixture with nitromethane? The wrong oil stock used with nitro and "kaboom" goes the combustion chamber rather than proper combustion. An interesting way to test your oil if you plan on running nitro in a drag bike is as follows: Soak a cotton ball in nitromethane then soak it in your sample of motor oil. Then move it to a safe place and light it from a distance using a match on the end of a yardstick. You may have an explosion which is bad, a shower of sparklers which is poor, or perhaps a blue flame which is good.

Racing oils are only suited for the race track. They are one-day oils, intended for a short glorious life rather than a long life in mediocrity. Besides, you'll only form gums and varnish in your street engine if you pour in race oil instead of the necessary street oil. Save the heroics for the strip. The same goes for two-cycle street oils versus racing oils except that the danger is more real in bikes. Race-type two-cycle oils are intended to be premixed about 40.0:1 gasoline-to-oil ratio. The 50 weight racing oil is unnecessary for street use and is sometimes hard to find. Proper street two-cycle oil is 30 weight stuff with cleaners and dispersent additives to combat deposit problems. Street oil is mixed about 16.0:1 by the injection system which has to be lubricated.

TWO-CYCLE OILS

It would be easy to tell you to follow manufacturer's recommendations about motor oils, but we cannot. Bike designers are not oil designers. Follow the recommendations of a good two-cycle oil manufacturer and you can hardly go wrong. This means knowing the people who make your brand of oil.

Another reasonably good way is to buy oil products packaged and labeled by the bike maker for his bike, or by the car maker for his car. But just as there are good bikes and poor bikes, there are good oils and poor oils. So we've listed some recommendations for you at the end of this article.

We hope you've understood the message that two-cycle engines are tougher on oils than other types. Yes, and they are tough on gasoline, too. We suggest that you do not buy no-lead or low-lead gas for any two-cycle. We also suggest that you buy your gas from a relatively new, well maintained gas station. Too many old stations have rusty tanks part full of water, dirt, sand, and plain crud. In a four-cycle engine most of this passes thru the engine causing little harm, but in a two-cycle there is serious crankcase contamination and combustion deposits elsewhere as a result of dirty fuel. Furthermore, low-lead or no-lead fuel does not give clean operation in a hot two-cycle which actually needs premium fuel.

In recent years the political movement for cleaner air has resulted in numerous smog control systems, the most efficient of which, envisioned for cars of the future, will not work effectively in the presence of lead. Ironically, lead itself is not a major pollutant; it is removed from gasoline only because it tends to erode the thermal systems and coats the catalyst in the catalytic reactors of smog devices.

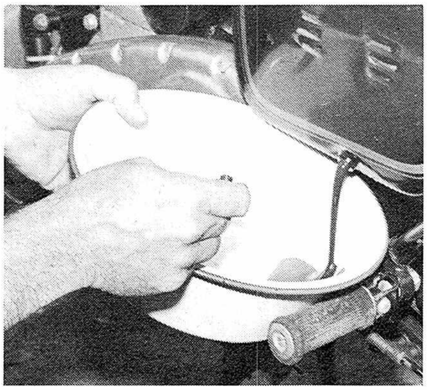
Many companies are removing or reducing the lead content in gasolines due to increasing public pressures. No-lead or low-lead fuels are "in" on the political platform. Unfortunately most engines do not like non-leaded gasoline. In fact, more lead is being used today because the driving public wants decent performance and it is buying more premium fuel than ever before. The real danger in omitting lead from gasoline is to the two-cycle engine. In fact, it's disastrous for the bike owner who innocently purchases no-lead gas because he'd like to contribute less pollution into the atmosphere. The sludge and varnish that quickly forms in the crankcase and around the rings will eventually produce excessive blowby and exhaust smoke. That's not progress.

LUBRICATION

Why does all this happen? The answers came from the president of Torco Oil Company, Bob Lancaster, who has devoted a great deal of research into the two-cycle lubricating business. Bob calls the two-cycle a "reciprocating blow-torch" quite distinct from its four-cycle cousin. When lead is withdrawn from gasoline the octane rating (needed for good anti-knock characteristics) takes a sharp nose dive. So for better anti-knock at low cost, chemicals related to the aromatic family are put into the pump gasoline as a substitute for lead. These added low-boiling stocks are not highly refined. That is, they are not pure generic chemicals. They are perhaps closest to generic Benzene, Toluene, and Xylene. Pure Benzene would be an excellent fuel additive but it's too expensive for the oil companies. Benzene is a fine racing fuel. It burns cleanly and exhibits an octane number above 120. Unfortunately, Benzene like all the aromatics, is not so cheaply refined into a pure state as is octane which is a paraffin.

Keep in mind that low-boiling fuels are quite volatile and have better anti-knock ratings for one main reason—they burn faster in the combustion chamber. Low-boiling fuels vaporize and ignite more readily in cold weather. Generally, the more fuel that completely vaporizes, the cooler becomes the charge. Today's pump gas is about 10 percent oil which is OK. However, the more oil you have in this kind of fuel, the more you have the following—slower combustion, less vaporization, more knock, more tar and sludge deposits.

Watch out. We're not saying oil in the fuel is bad. Only that too much oil and not enough fuel can bring about detrimental results to proper engine operation. The crankcase of a two-cycle is very hot and acts like a "still." That is, it boils (vaporizes) the light ends in the gas right away for transfer to the combustion chamber—leaving the heavy ends in the crankcase. There is no significant sludge problem if the light ends don't leave residue or tars on evaporation. The problem with the low-lead fuel is it does leave residue. Low-lead stuff doesn't always evaporate cleanly nor does it burn "clean" and may gum up the exhaust also. Premium fuel is best for two-cycles. It evaporates well, has good anti-knock, burns "clean," and leaves a sanitary crankcase.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1. Regular oil changes (while oil is hot) will insure that oil "worn out" from oxidation won't let your engine down at some crucial moment.

2. A "sanitary fill" in some dark corner of the yard, or along the side of the house to keep termites away, is the best place for this mess.

The amount of oil and gas you should put in a premix two-cycle engine is determined by what weight of oil you're using. A 30 weight oil calls for a fuel/oil ratio from 16.0:1 to 24.0:1, but 40 weight oil needs a ratio from 24.0:1 to 32.0:1 while 50 weight oil likes a ratio from about 32.0:1 to 48.0:1. Injection oilers in two-cycle engines like 30 weight two-stroke oil best unless the manufacturer recommends something different. In addition we can vary the injector pump stroke via throttle setting.

Another ratio, the air/fuel ratio is affected by the amount of oil in the fuel going thru a two-cycle. Yes, the air/fuel mixture is enriched automatically when you run a "drier" fuel/air mix if there's more burnable fuel in the gasoline. Too much oil shows up in a two-cycle with "wet" plugs and an oily exhaust.

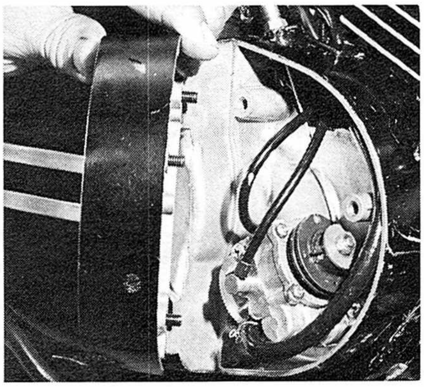
Heat is the biggest danger to a two-cycle which could seize the piston within the cylinder. Some years ago, friend Eric Rickman discovered this one day after a long hard run on his overloaded Yamaha when he backed off the throttle too quickly. In a premix engine, when you chop off the throttle you stop the lube oil, too! The instantaneous cooling of the cylinder around the piston combined with the lack of oil produced a wavy 100-foot skid mark and one shook photographer! Injection oiling systems prevent such things from happening. However, two-cycle racers prefer to mix their own.

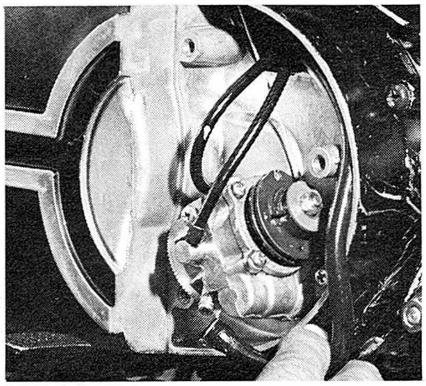
CONTACT=FRICTION=WEAR?

Somebody occasionally says, "oil's oil." Such a statement reveals a fundamental lack of knowledge about lubricants and the friction process. Any amount of EP testing soon shows how different oil samples yield a wide spectrum of test results. If an oil film could completely prevent contact between rubbing surfaces, then there would be no need whatever for additives. No contact—no friction—no wear. It's that simple. But complete separation between metals rarely occurs.

It's definitely true that lubricants must fight friction, however a little bit of friction is necessary for the lubricant to do its job. An excessive amount of friction creates tearing, galling, and eventual destruction of the rubbing surfaces to produce a great deal of surplus heat energy. It appears the primary function of oils and greases is to protect rubbing surfaces and by staying between surfaces to wear-proof them against the damage of sliding or rolling contact. Friction is not equal between surfaces of different materials. For example, the characteristics of steel-on-steel are different than those of steel-on-copper or copper-on-lead or wax-on-brass. Frictional characteristics naturally vary depending on the exact lubricant between different kinds of materials. Some lubricants are more effective than others in reducing friction while some are better in reducing wear. One of the most valuable properties of oils is their ability to clean and cool rubbing surfaces.

We will be discussing boundary conditions and hydrodynamic conditions. By definition, a boundary lubrication condition is one where there is some metallic contact even with a lubricant present. The most destructive boundary condition is a low-speed, high-load situation where surplus heat is being generated. An ideal hydrodynamic lubrication condition is where there is no metallic contact occurring because of high surface speeds with perhaps light loading. We

3 

4 

3. Periodic adjustment of the pump will keep two-stroke auto-oilers from smoking up the atmosphere and fouling plugs.

4. Check the lines to see that they're clear. Replacing opaque lines with transparent ones lets you check oil flow while under way.

are most likely to have a boundary condition with too thin of a lubricant, whereas a high viscosity lubricant such as a gear oil would tend to develop a hydrodynamic condition. It is important to realize that oil additives such as phosphates, sulfates, amines, and chlorinated compounds are used to protect against boundary conditions. Additives reduce surface tearing and encourage "healing" in order to reduce wear.

In a boundary situation many, many junctions are constantly forming, bending, generating and absorbing heat energy, perhaps shearing off whiskers as wear particles, and reforming new junctions. A good lubricant reduces friction to about 10 percent of the unlubricated value. Junction density (the average number of junctions per square inch) could be many thousands or many millions of junctions per square inch. Modern frictional studies prove that friction greatly depends on the total number of junctions existing at a given instant and on the average strength of the bond at each junction. Very flat, very smooth or polished surfaces have the highest junction densities and will score easily and severely. Scoring is the most destructive kind of wear. A lubricant is supposed to encourage normal wear which is an extremely gradual process of material removal. There is nothing that can stop wear altogether. Slowing wear is not difficult for a good lubricant so long as the surface finish and choice of materials reflects good engineering.

The following surface conditions would tend to develop high junction densities—extreme smoothness, a polished condition, surfaces of equal hardness, super-clean surfaces free of oxide film, surface temperatures near the melting point, a very slow rubbing speed, high applied loading. If two or more of these high-friction conditions were prevalent at the same time, the two surfaces would weld together and seize totally.

It is often curious to discover that a friction member (like true love) never moves smoothly. Its motion is quite jerky, even at high speed or rpm. The only time a clutch or *brake* is smooth is when it's full on or full off. In other words, friction between members moving at different speeds always causes an almost imperceptible change in speed of both members (a shuddering or vibration). You see, if junctions are constantly forming and reforming, their number is changing and so friction is changing from one millisecond to another. The result is a grab-release situation.

FLUID FRICTION

We should mention a few words about fluid friction which we sometimes call viscous drag. This fluid friction is greater with high viscosity oils and naturally less with lower viscosity oils. It's easy to see that very high fluid friction would tend to slow down the mechanism that it is protecting. However, fluid friction is very much overrated in motorcycle or automotive use. The real enemy that lubricants are supposed to fight is metal-to-metal contact in a boundary condition. Any attempt to substitute a very light oil to reduce fluid friction becomes a self-defeating measure because you are then going to substitute a great deal of metal-to-metal friction in place of a slight amount of fluid friction. In other words, if you have a high load situation such as in a race machine you must reduce metal-to-metal contact in order to deliver the highest amount of horsepower to the rear. The way to do this is almost always with a higher viscosity lubricant. Viscosity must match the load. Remember, the real enemy is metal-to-metal contact.

The problem of using too low of a viscosity is particularly troublesome in two-cycle bike engines where fuel dilution is such a problem. In the first place, gasoline has no business in the crankcase of an engine, any kind of engine, but in a two-cycle we're pretty well stuck with it. This means that oil chemists must be part magician in order to provide enough good lubricant to protect the bearings, pistons, rings, and other sliding parts in a two-cycle engine. Bob Lancaster of Torco Oil Company has commented that the problems in designing a good two-cycle oil are truly staggering.

Sometimes liquids can exhibit the characteristics of a solid body. Watch a flat rock skipping across water. The water acts like a solid surface so long as the rock is moving rapidly. When the rock stops, it sinks. Similarly, a rapidly rotating shaft in an engine bearing "skips" on an oil film wedged between the shaft and the bearing. This only happens during hydrodynamic lubrication. Friction under hydrodynamic conditions is the lowest possible anywhere because there is zero metal-to-metal contact. No junctions exist. The only drag is viscous from the oil itself. The measured friction on the shaft is only 1/5 to 1/2 of one percent. Hydrodynamic conditions are due to very high shaft speeds on a film of high-viscosity oil. The oil clings to the shaft so that it is continually being drawn (wedged) between the shaft and the bearing. Absorbed films due to additives aid this action greatly. But if the shaft speed slows down or if the oil viscosity drops for any reason such as heat, there will be an immediate reversion to boundary conditions. The best ways to maintain hydrodynamic lubrication are (with a near-polished or "micropolished" journal, a nitrited crank is best (high surface hardness), use of fine steel wool on the bearings (slightly roughened to reduce the number of junctions), use of 50 weight or higher racing oil; finally, never lug your motor.

Hydrodynamic lubrication is not restricted to only engine bearings. The principle applies to most mechanisms being lubricated. Piston rings sliding on a cylinder wall ride a film of oil like circular Hawaiian surfboards. Gear teeth in transmissions and rear ends trap quantities of oil between

meshing teeth and so resist metallic contact to a great degree. That's why 140 weight gear oil is preferred in an automotive racing differential. Present day gearboxes seem to be inadequately designed for racing. We see a large number of boxes whose gears have "frozen" on their mainshafts. The reason is insufficient flow of oil on the mainshaft and around the inside of the gears. Hydrodynamic lubrication needs lots of cool oil.

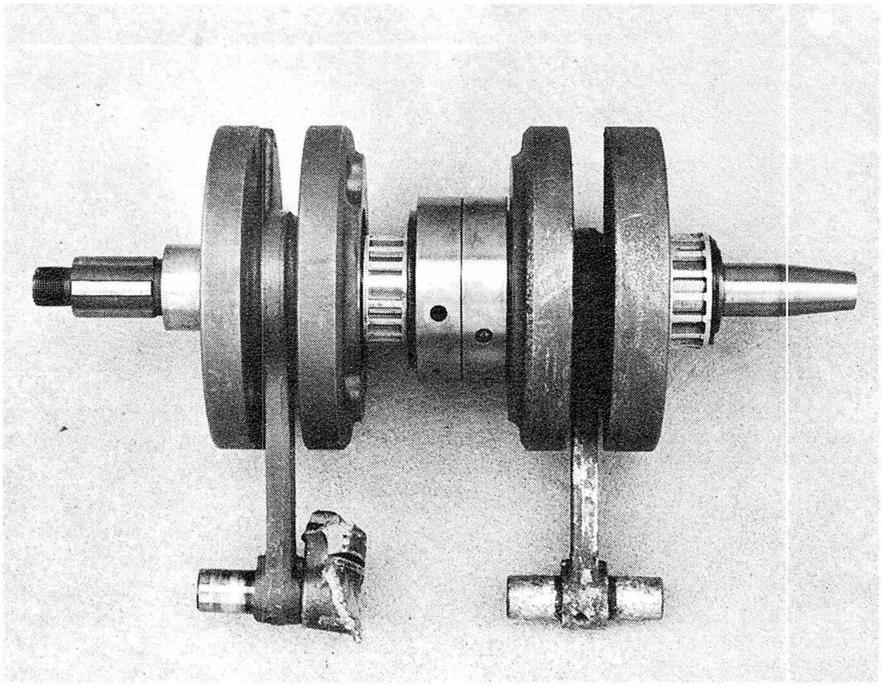
FRICTION COEFFICIENT

We've talked a lot about friction and now we'll discuss the coefficient of friction. Friction itself is a complex process that takes mechanical energy and converts it into heat energy. However, the coefficient of friction is a convenient way of measuring friction mechanically. Look at a 100-pound block of wood sitting on a flat surface. Ask yourself, how many pounds would it take to drag that block of wood slowly a short distance? Well, it would take 20 pounds of steady pull if the coefficient of friction between the wood and ground surface were .20.

A 100-pound block of rubber lying on very smooth asphalt might require 95 pounds of pull. Hot rubber would of course require a pull more than the weight of the rubber, or over 100 pounds. So you see,

$$Cf = \frac{\text{pull}}{\text{weight}}$$

There's a natural tendency to exaggerate the importance of a low Cf. EP is far more valuable. The misleading factor about Cf is that it is taken under low-load circumstances. Only the weight of the test body is pressing down on the junctions. The heat generated is low and the extent of plastic deformation is low. The amount of welding taking place is also low. Compare this situation with one where 50,000 or 100,000 pounds are pressing on one square inch of rapidly moving surface such as in a differential. What a comparison! This high-load situation is what EP is all about. That's why hypoid gear lubes need lots of EP additives. Palmitates, sulphates and phosphates are some effective EP (or anti-wear) agents which may not necessarily exhibit a high lubricity (low Cf). High viscosity oils using active agents such as chlorinated hydrocarbons yield both a high EP and high lubricity.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Low Cf means high lubricity. This is indeed valuable in testing because so much can be learned from Cf figures. Wear rates of different materials usually do correspond with lubricity figures in most cases. It is known that the least wear occurs with a very hard surface riding on a very soft surface. The Cf is low, with or without oil. Lubricity is a tool we cannot do without. The things we've learned about what materials wear best together have come from Cf figures and microscopic photography.

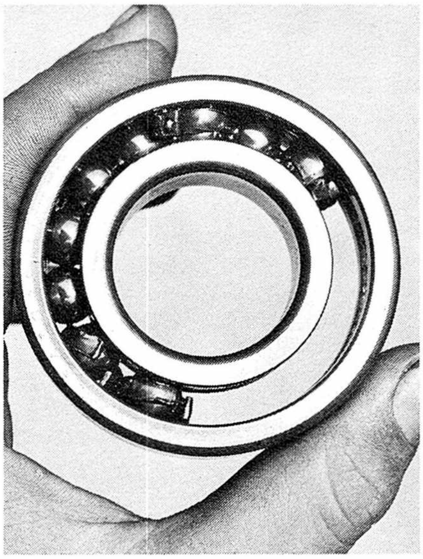
A remarkable thing impresses all researchers in the field of friction and lubrication. It's the strange fact that friction surfaces somehow know best how to finish themselves towards a condition of least friction. Surfaces that are too smooth try to roughen-up slightly for easier sliding. Surfaces that are too rough try to smooth themselves for less friction. You could perhaps compare the phenomena to that of water seeking its own level. The smart engineer is one who prescribes a surface finish that the metal likes right from the beginning. That way during break-in, the surfaces will not have to undergo a drastic lapping-in situation which of course leads to scoring. If the roughness of the finish is out in left field, there is simply no hope. Also besides surface roughness there's the question of what finish pattern is best. The only answer for that is the crosshatch pattern which has proved itself for many years. We like it on cylinder walls, bearing inserts, shaft bores, valve guides, and bearing races. Research Brush Company in Los Angeles has an excellent line of finishing brushes.

Wetting is something related to lubricity. It's the ability to penetrate and work into tight places. Metals are not so dense on their surfaces. Lattice structures of cast materials such as iron and aluminum are relatively weak. Their surfaces are actually porous. But all metals have oxide coatings that are susceptible to wetting agents. Amos Corgiat, now Vice President of Valvoline Oil Company once donated a wetting additive sample for us to test. We found that overnight the oil had crept 10 or 12 inches up a previously dry steel rod that was left sticking out of the container. That was amazing, to say the least.

GREASE

The word grease is reserved for lubricants in a near-liquid (plastic) state. A grease is a mixture of some lubricating oil and a thickener or soap. Grease bases like lithium, sodium, potassium, calcium, or barium will determine the basic physical characteristics of the grease. The physical make-up of a grease tells us where it can be used. But it's the oil in the grease that does most of the actual lubricating. A good grease is 60 percent oil.

Greases have their additives, too. There are zinc oxides, graphite, molysulfide, teflon and lead. These are filler ingredients, not actually in solution. These fillers are sometimes good boundary lubricants where sliding



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1. The best of oils cannot stand up to constant overrevving. Honda twin crank self-destructed with dirty old oil.

2. Regular oil changes can help you avoid disaster. Crankshaft bearing cage of Ducati disintegrated. Owner discovered shavings and broken pieces during oil change, escaped complete destruction of engine.

speeds are low. The best common load carrier is perhaps a mixture of zinc-oxide and lithium grease.

Sticky greases are necessary where some lubricant must cling to an awkward surface, such where the use of oil is impossible. It's still the oil which bleeds out of a grease that provides lubricity. The body of a grease acts like a reservoir for the oil held within. Most greases are intended for anti-friction bearings (ball or roller) or special cases of low-speed sliding conditions, since there is a distinct difference between low- and high-speed lubrication. And there is an even greater difference between rolling friction and any kind of sliding friction. The job of lubricating a rolling condition is one heck of a lot easier than lubricating a sliding condition.

Never use a grease in place of an intended oil. Greases may be fine in wheel bearings, but they would not be good for assembling bikes or engines for racing purposes. Nor should you ever mix greases of one type with another type due to the chemistry of the inorganic base compounds. Clean your parts thoroughly and avoid all chlorinated compounds when working with greases of any kind. Chlorine plus grease makes salts which are abrasive, such as sodium chloride or lithium chloride. Also, keep nitro fuels away from greases.

We cannot overemphasize that overfilling with grease (more than 1/3 to 1/2 full) leads directly to lubrication failure. An excessive amount of grease churns and creates a great deal of heat. Greases require room to expand and move around so that the oil in the grease can circulate to where it's needed. Use only the proper amount of grease.

Greases are graded by a *penetration* tester. A very heavy grease takes a lot to be penetrated. That would be a grade 6. A grade 0 grease is very oily and is easily penetrated.

We feel that lithium grease has the best advantages for motorcycle and automotive uses in cold wet weather or hot and dry. Lithium grease is especially good if it contains zinc oxide as an additive, along with a high EP oil mix and is corrosion inhibited. Valvoline X-All is one such grease. It's white and is often called white lead which is a misnomer.

In case you've run your bike through deep water or continuous rain, it'd be a good idea to repack your wheel bearings. A little water does not really harm good grease if you change it regularly. The additives in the grease (and in the oil in the grease) can't live forever. They deplete and require changing like anything else. In fact when the oil content of a grease drops to about 50 percent, the grease quits lubricating because not enough oil can bleed out of the thickener to give adequate protection.

"MIRACLE" LUBRICANTS

Since World War 2 we've heard a lot of bally-hoo about solid film lubricants such as graphite, molybdenum disulfide, and teflon. Some salesmen for these products really have silver tongues. The claims they make are pretty unrealistic. At best you'd be lucky to not damage your bike or some of its expensive parts. These "miracle" substances actually can interfere with good lubrication if you have a decent oil or grease. They can coat the metal surface, preventing the oil additives from reaching the surface in order to react with it. Solid films of graphite break down at relatively low frictional temperatures by changing allotropic form into a kind of carbon. Molybdenum disulfide disassociates under friction to raw molybdenum metal and sulfur gas which is highly acidic. It has been well known that most solid-film chemicals will lower the EP of a good oil. The reason the dry-films became well known is that they seemed to raise the lubricity of straight mineral oils. But we've seen that mineral oil alone is not enough. Nor is lubricity a critical factor without also considering EP.

Please don't go away with the impression that graphite is altogether bad because in some specialized circumstances it's quite good, such as in the presence of water vapor or at cryogenic (extreme cold) temperatures. Without some moisture present, graphite (in all its forms) is no lubricant. In a vacuum such as space, anhydrous graphite (without water) becomes a substance that does not shear easily and would freeze a mechanism. Mixed with an oil, graphite and moly particles (no matter how finely ground) are at best only slightly soluble.

The one very successful dry-film or solid-film chemical is a phosphate coating called Parko-lube or Parkerizing. This is the familiar dull black material on all new flat tappet camshafts and gears. This process is great for protection during break-in and it combines very well with oil additives. In short—it works.

Another workable solid ingredient is lead. It's good in gear lubes for hypoid rear ends which generate appreciable heat and require the highest EP lubricants possible. Such lubricating oils are called SCL for sulfur-chlorine-lead. But watch out never to use an SCL oil in some gear box that contains copper alloys like bronze or brass. SCL decomposes these metals. But it is truly beautiful in all-steel bike components. You can make your own SCL lube by squirting some of Ashland's Chain-Life into fresh gear oil. Never mix Chain-Life and grease.

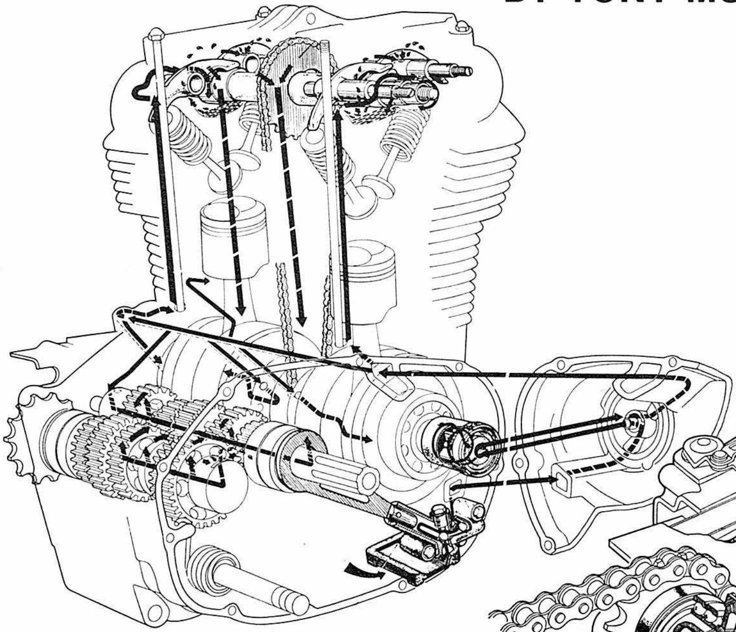
Lead additives in gasoline do more than resist knock. They lubricate exhaust valve stems and seats for much longer life. Lead in fuels helps the rings and cylinder walls, too.

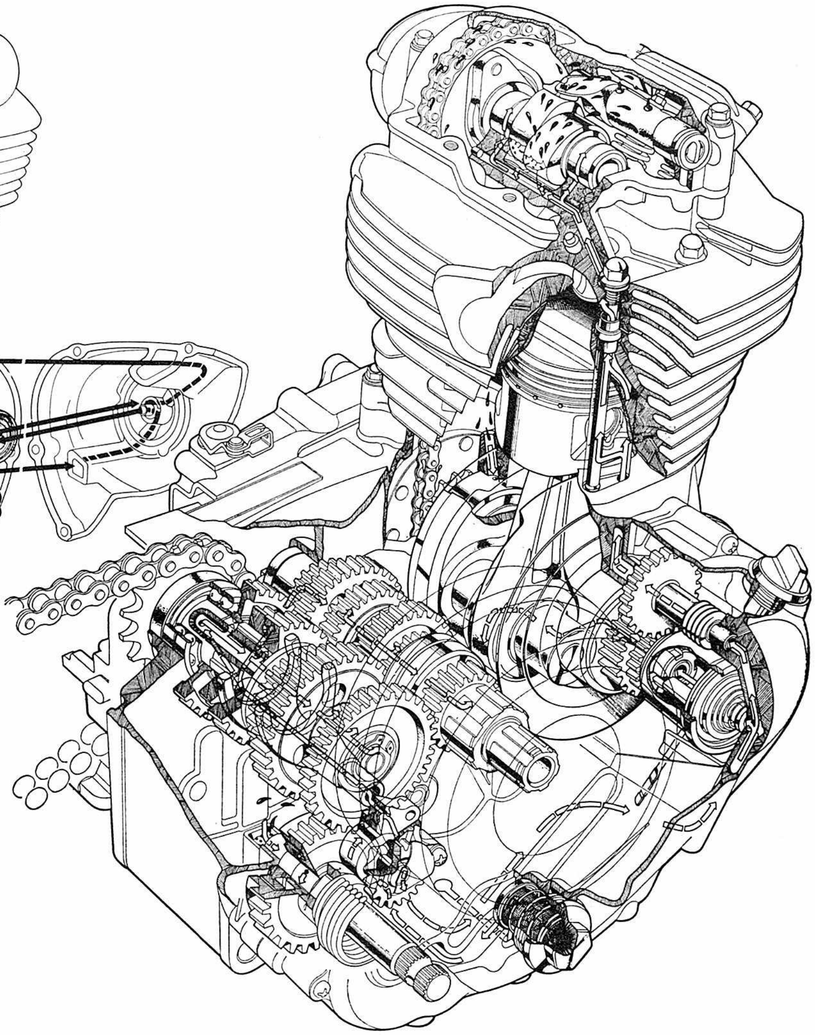
Oils most certainly do wear out. It isn't obvious when it happens, at least not to the average motorist. Oxidation takes its toll. So does additive depletion, which is the gradual usage of the load carrying agents. When the additives are gone, what's left besides contaminated mineral oil and oxidation products? Do you want good results? Change your oil and the filter no more than every 2000 miles and you'll go a long way. And check your bike air filters too. We've seen reports of *lava* deposits(!) being mistaken for carbon deposits in two-cycle engines. It seems rock dust gets thru those air filters too easily if you're careless.

OIL SYSTEMS

Engineers have used many routes to ensure proper lubrication.
Here is a look at some of them

BY TONY MURPHY



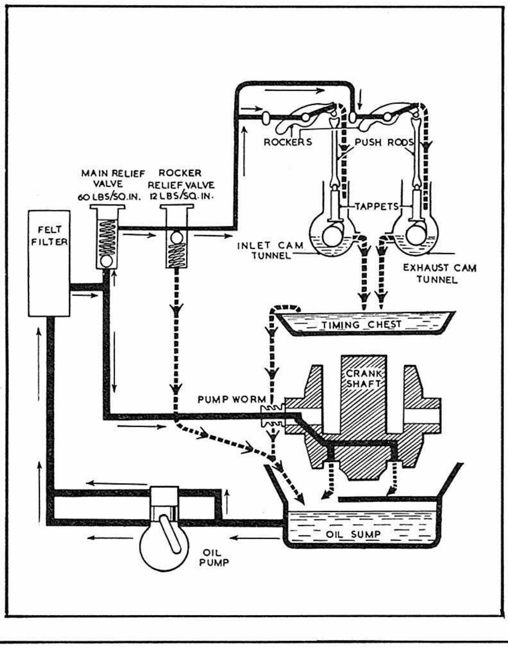


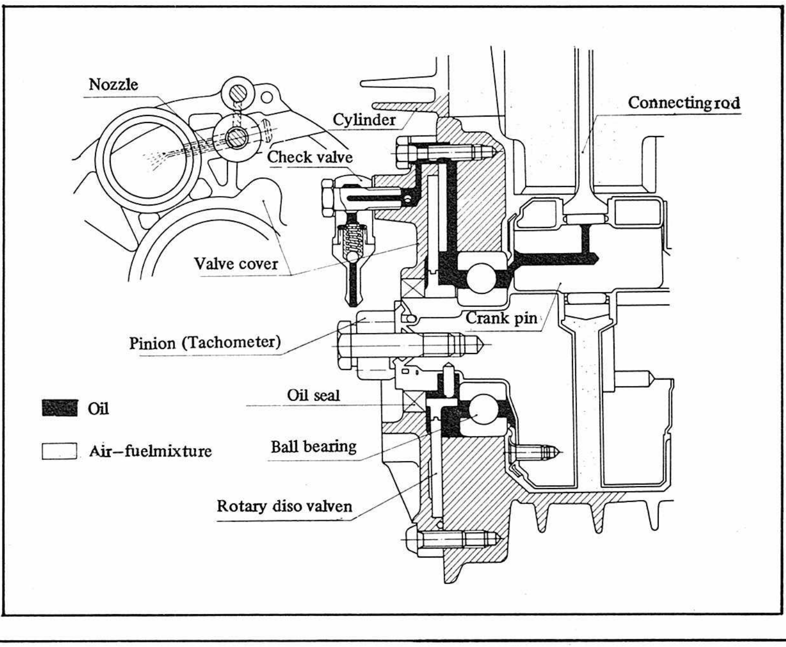
1. Honda twin picks up oil from crankcases and pressure feeds both engine and trans. Oil then falls back into crankcases to be reused.

2. Cutaway of Honda 250 single shows route of oil from pump to trans, crankshaft and overhead cam. Oil is cleaned by centrifugal filter in cover.

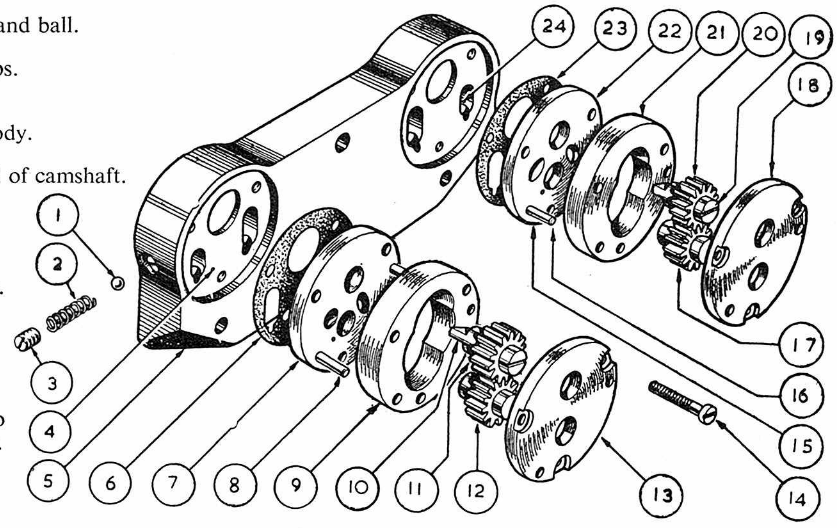
3. Typical of British vertical twins, this schematic follows the oil from pump, to filter, crankshaft, valve mechanism and back to crankcase.

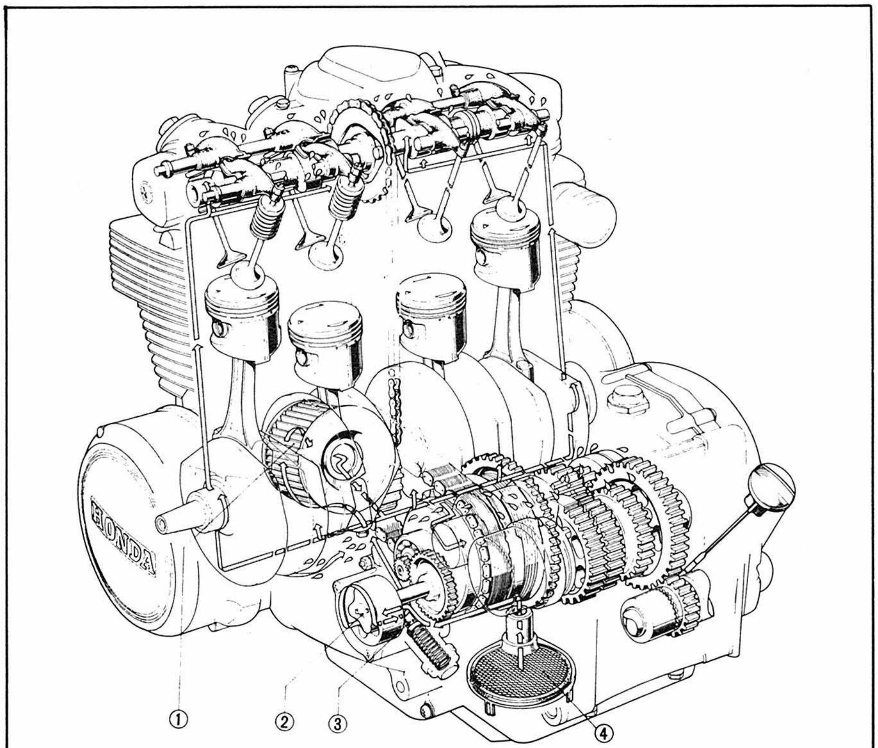
4. Many two cycle engines employ a pressure oiling system. In this case, oil is fed to the crankshaft main bearing then to the connecting rods.

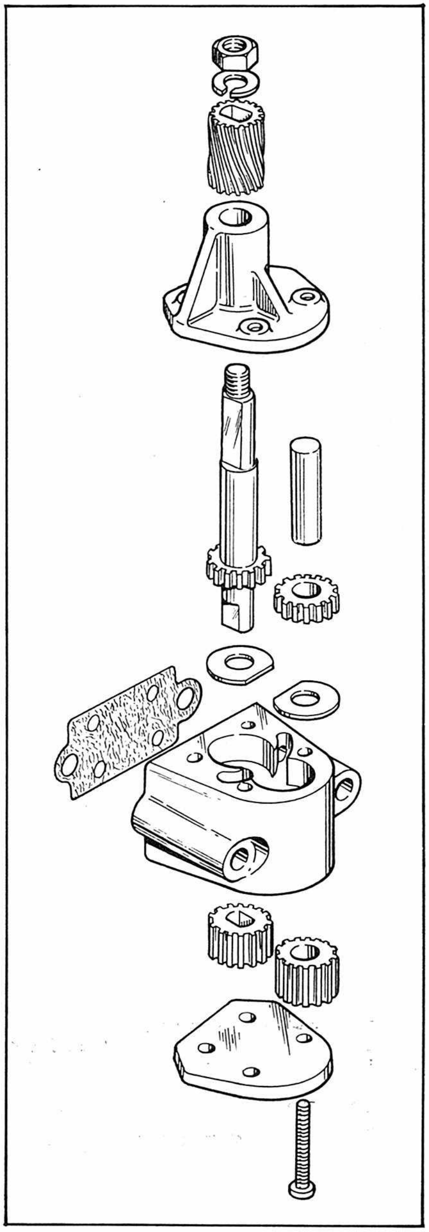




1 Ball, for non-return valve.
2 Spring, for non-return valve.
3 Plug, retaining non-return valve spring and ball.
4 Bleed hole.
5 Plate, carrying oil feed and return pumps.
6 Paper washer for oil return pump.
7 Back plate of oil return pump.
8 Dowel pin, locating pump plates and body.
9 Body of oil return pump.
10 Dog end of pump gear to engage in end of camshaft.
11 Driving gear, for oil return pump.
12 Driven gear, for oil return pump.
13 Front plate of oil return pump.
14 Screw (1 of 6) used to retain plates and bodies of oil pumps to the carrying plate.
15 Back plate of oil feed pump.
16 Dowel pin, locating pump plates and body.
17 Driven gear, for oil feed pump.
18 Front plate of oil feed pump.
19 Screwdriver slot, to enable driving gear to be correctly positioned during assembly.
20 Driving gear, for oil feed pump.
21 Body of oil feed pump.
22 Back plate of oil feed pump.
23 Paper washer for oil feed pump.
24 Bleed hole.



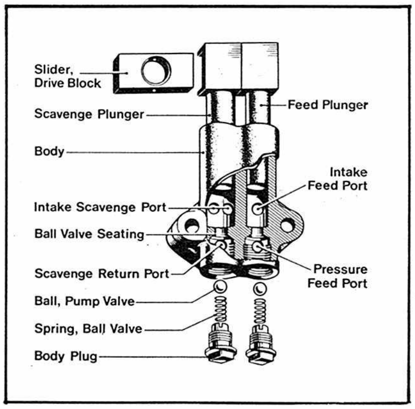




5. Multi-cylinder engines like this Honda have a mass of moving parts that need lubrication. Oil pump is located in left crankcase and must oil both engine and transmission.

6. Plunger-type oil pumps are operated by an eccentric slider block. One of the plungers feeds oil to engine while the other one pumps oil from engine back to the oil tank.

7. Gear pumps are driven off of engine, speed of the pump being adjustable by changing drive gear reduction. One set of gears pump oil, the other set return it to the tank.



FOUR-STROKE ENGINE REBUILDING

A complex and involved task can reap financial savings, but rebuilding requires close attention to details, patience and lots of time spent with your nose in a service manual

BY JOE MCFADDEN

The motorcycle engine is a rather precision device, having been developed over the years by competent, dedicated individuals to a degree of sophistication found in no other production form. Indeed, many of the technological developments in the horsepower art were pioneered by the developers of motorcycles. Naturally, such a device is *not* going to respond very well to being zipped apart and thrown back together again like a lawnmower or tractor engine; with a dib here and a dab there to obtain final tuning. One degree; one thousandth of an inch too little or too much can make the difference between "go or blow."

In this article, we are going to discuss the correct procedures and techniques to use in overhauling a four-stroke engine. More impcrtant, probably, we are going to mention the many pitfalls which the neophyte motorcycle engine rebuilder encounters, and how to avoid them or overcome them; and we use the term "neophyte" advisedly, for no matter what your mechanical "savvy" with boat, automotive or jet engines, if you've never before tackled a motorcycle engine, cocksureness will leave you in trouble.

If, on the other hand, your mechanical experience is more limited, don't be discouraged. If you are possessed of no more than one thumb on each hand, are willing to spend some time *reading*, and can follow written directions, you can do just as good a job, if not better, than a pro. For those of you who have had previous mechanical misfortunes with the motorcycle engine, we advise you heed the words of this humorous but sadly true American maxim: "When All Else Fails, Read The Directions."

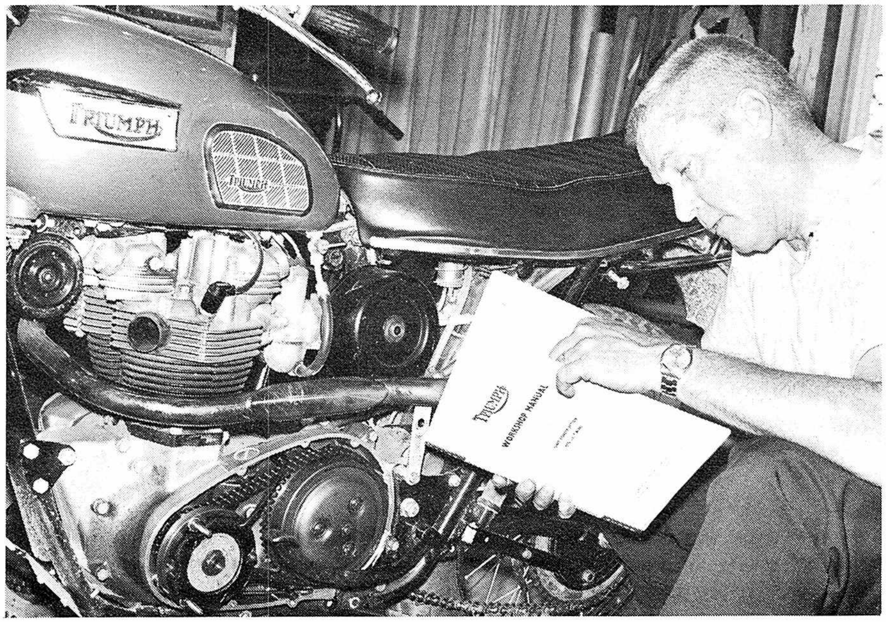
If, on the following pages, you don't see any pictures of your particular engine, *don't go away.* The methods of working on the four-stroke engine are common to all, as construction and engineering similarities abound. However, if the following procedures or directions differ with those of the Shop Manual written for your particular machine, stick with the manufacturer's advice. Bear in mind, though, that some shop manuals become outdated regarding specifications, especially with newly developed engines. When this happens, your dealer receives service bulletins; if you advise him of the model, year and serial number of your machine, he will gladly inform you of how best to update it. You see, engines built with out-dated parts or superceded instructions cause him anguish too. He doesn't want to reap the spurious profits of selling you a second hundred dollars worth of parts; not when it's going to cost him a sale at trade-in time.

ORGANIZING THE JOB

Start out right, it will save you a lot of time and grief. Advance planning reaps many dividends in any type of mechanical work; lack of it is time consuming, wallet-leaning and exasperating. The following items are essential prerequisites to ensure a first-rate job.

A clean, well-illuminated working area with a sturdy, uncluttered workbench will start things off right. Ventilation should be adequate, but not excessive. Breezes blow dust and dirt particles into open crankcase mouths and other delicate areas, a no-no if ever there was one. Be sure you have a fire extinguisher handy, even if it's only one of the small ones available as a motorcycle accessory. Additional—and inexpensive—safety items should include grounded plugs for power tools; goggles for use in grinding, drilling, chiseling and power wire brushing; pot-holder gloves or welder's gloves to prevent burns when handling heated parts; sturdy work shoes or boots and a sufficient number of suitably strong containers in which to store and carry parts. Such items as crankshafts, cylinder barrels and heads tend to obey the laws of gravity, especially when stored in soggy-bottomed cardboard boxes.

Appropriate washing containers for parts rinsing and degreasing should be immediately at hand. Metal baking pans are convenient, the shallow ones for containing recently disassembled, still oily parts, deeper types (three-



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inch or so) for rinsing or cleaning.

Solvent is definitely preferable as a cleaning agent. It is much safer than "Brand-X" gasoline, being far less flammable and easier on the lungs. Five-gallon buckets (with tight fitting lids) about ⅔ full, are ideal for degreasing the "heavy stuff" like flywheels, cylinder heads, crankcases and the like. Clean grease cloths, or reasonable facsimiles thereof, are a necessary adjunct. Avoid using rags or cloths which shed lint and threads.

TOOLS AND EQUIPMENT

Few weekend mechanics can afford the elaborate, time saving equipment found in most shops, but a vise is practically a must. Ditto for at least a quarter-inch drill motor. A small bench grinder can be very helpful, but you can work around it.

Good quality hand tools are essential, needless to say. The tool kit which may have come with your bike *isn't* sufficient to do an overhaul. You should have the appropriate standard tools, American, Metric, or British Whitworth, depending on the make of your motorcycle. Don't try to work around this by using American size wrenches on Whitworth or Metric bolts and nuts. You will only succeed in rounding off some rather expensive—and not always available—hardware. (Don't let those metric allen screws sneak up on you.)

Assuming you don't own a power impact wrench, buy one of the hand impact tools and the necessary bits. They are available as an accessory item at most motorcycle shops and many tool dealers. Again, these will prevent damage to primary, timing cover and other screws and perform well. Without one you will be unable to remove many screws and nuts; items which *must* be on tight to prevent oil leaks.

Assuming you *do* have a power impact wrench to work with, a word of caution: Over-zealous application of torque to mild steel screw heads causes prompt decapitation of said items, which then necessitates the painful Ezy-Out treatment.

If you don't have a shop manual *buy one!* The rider's manual doesn't cover engine overhaul and is generally geared to the tool kit under the saddle. The shop manual outlines each operation of the overhaul, along with factory recommendations for accomplishing it with a minimum of trouble. We advise you to read through the whole manual before beginning the job, then consult the individual sections, specifications and diagrams prior to doing the operation described. In so doing, you will be able to "stay out of the woods," as the expression goes.

Listed in the workshop manual for your machine are, no doubt, a variety of special tools to assist in the teardown procedure. You can usually purchase all of these tools at your dealer, or he will order them for you. Happily, we can do with only one or two, so read *carefully* to determine which are absolutely necessary for disassembly; they're usually expensive. Gear pullers can generally be bought or borrowed from automotive parts houses. Clutch hub pullers are usually cheap enough to purchase, and are necessary if your engine is British. As an alternative to buying the tools required, you can dismantle the engine as far as possible, tote it down to your dealer and have his mechanic remove them. The charge for this is usually minimal. Our advice along these lines is this: If you plan on repeating the overhaul, whether on your own bike or on a friend's, buy the tools you need. Their cost will be more than covered by the labor dollars you are saving, and will save delays and legwork in the future. Moreover they retain their value well.

You may not be equipped to handle such things as boring, valve seat grinding, etc. Find out who handles this work, and be sure of their reputation for competence. Some auto machine shops are well acquainted with motorcycle components, but if you aren't sure, consult your dealer. He is either equipped to handle these chores, or has access to the people who can.

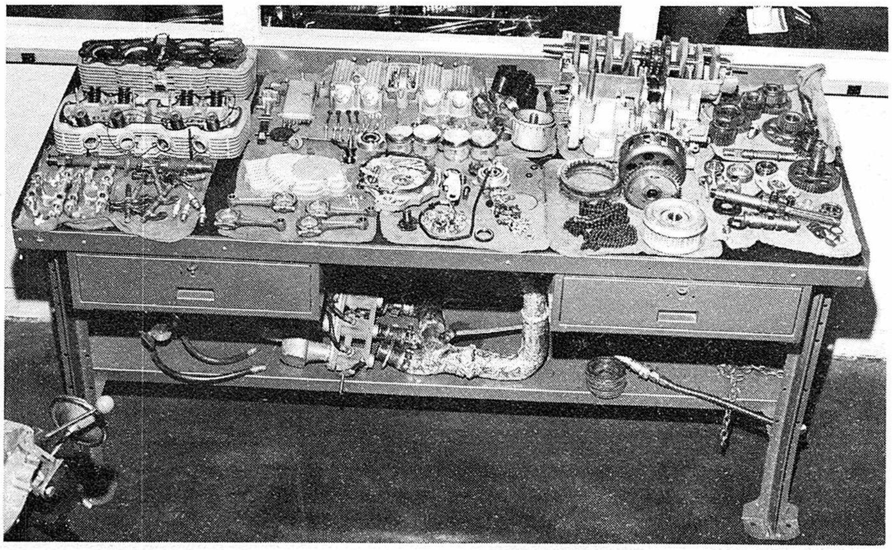
An overhaul can be accomplished at times for less than $50.00, but can run into several hundred. Motorcycle parts are expensive, and so is machine work. If you can't afford the parts *don't tear the engine down.* Parts may become lost or damaged from lying around, and you can wind up with a "basket job." Even a knocking, oil belching engine is worth more together than it is in pieces.

Patience is one item that is cheaper to own than to be without. Don't plan on working fast, unless you're a flat

1. Start out right by getting a factory service manual. Read through it before you start tearing things apart. Pay particular heed to sequence of teardown and need for special tools.

2. Be prepared for the task at hand. The enormous array of parts in a Honda Four requires a large work area and equal size shop bench.

3. Ask your mechanic friend about the 'tricks' of the trade. Holding a Honda cam chain with some safety wire keeps it out of the engine innards.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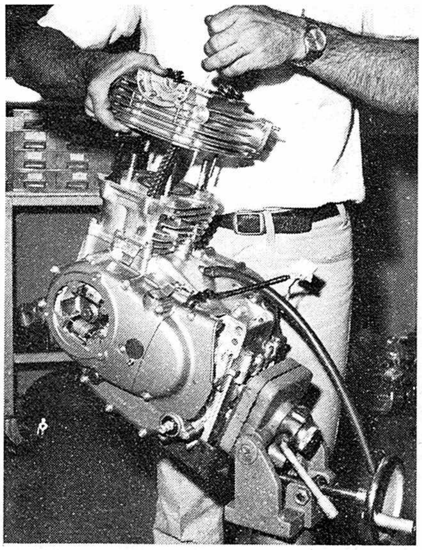
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FOUR-STROKE

rate mechanic with a lot of experience—in which event you shouldn't need to be reading this. Take each phase of the work slowly, and don't get ahead of yourself. Keep your surroundings tidy, and your work organized. Check and double check every procedure; take nothing for granted, avoid short-cuts and leave nothing to chance. If you find yourself becoming disgusted or exasperated at any point, wrap the job up until you're in a more cheerful frame of mind. Disgruntled mechanics do sloppy work and sometimes wreak havoc! It's your motorcycle, don't let it down.

ENGINE REMOVAL

You can make things easier at the outset by spending a little time and effort on cleaning the machine before you even start. A can of Gunk, a brush, hose and some rags will take a lot of grease and muck off. The bottom (underside) of the engine should receive particular attention. This done, drain *all* the oil from the engine and transmission. If the primary case contains oil, drain it.

The gas tank and exhaust pipes can now be removed. If possible, drain the gasoline and refill the tank with solvent. Otherwise, it is just as well to leave the gasoline in, and store the tank in a safe place. Be certain the gas taps aren't leaking; if they are, place the tank in such a position that they are above the level of the fuel. Empty gas tanks contain dangerous vapors and are prone to rust formation as a result of condensation. Exhaust pipes can be wrapped in paper and hung up out of the way to protect their chrome finish. Old coffee cans or paper bags are a convenient method of keeping the assorted screws, nuts and bolts separated. Label the containers. Outer engine cover screws, nuts, and bolts should not be mixed. Left side set in one container, right side in another. This will save a lot of inconvenience on reassembly.

The carburetors are the next order of business. Remove them (after draining) completely; don't leave them dangling from the throttle cables, they bruise easily. Wrap in paper wadding and store them in a small cardboard box. Disconnect the clutch cable if necessary, coil it and tape it to the handlebars. If the speedometer/tachometer cables connect to the engine, treat them in the same manner. The engine wiring harness is next. Disconnect it. Coil the harness and tie it out of harm's way to be certain it won't become chafed or cut during the removal process; this can cause confounding electrical problems later. The section of the harness leading to the frame should also be pulled up and tied out of harm's way. If your engine has a remote oil tank, drain it and remove the lines where they connect to the tank, unless they are easily accessible from the engine connections. Note: Examine the oil line connections carefully; make a mental note of which line hooks to which connection. If your memory sometimes fools you, buy a small notebook, and jot things down as you go along. Make diagrams of items which might confuse you on reassembly. They *may not* be illustrated in the shop manual.

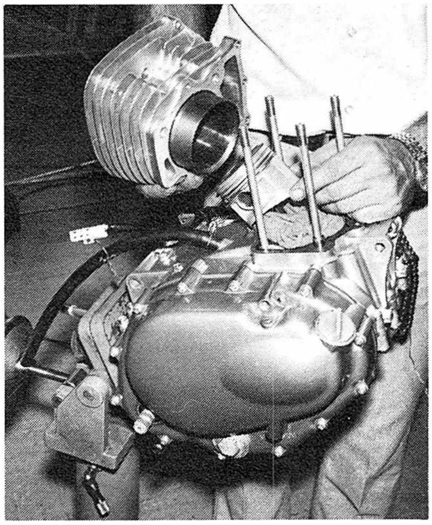
Upper motor mount brackets are the next to come off. Keep the assorted nuts, bolts, washers and brackets together. Spacers and brackets can be assembled back to the bolts, and the nuts threaded on part way. This will keep them together and sorted. It is sometimes more convenient to remove cylinder heads prior to undoing the lower motor mounts and final removal of the engine (this notably on British vertical twins). Before undoing any of the nuts and bolts, however, remove the rocker caps (Triumph) or cover (BSA). Rotate the kickstarter slowly until both intake valves are in the closed position. You may now remove the small nuts and bolts from the rocker housing to the head (Triumph), followed by the two large long bolts. The object is to take the pressure of the valve spring off the rocker box. Failure to do this, and removal of the large bolts first, will almost surely cause stripped studs or threads. On the BSA, this procedure permits the mechanic to depress the rocker arm at the valve with a large screwdriver, after which the pushrods can be easily removed. Repeating the procedure on the exhaust will facilitate removal of the rocker shafts (after pushrod removal). The object of the technique is to prevent damage to engine parts. Short-cut operations save minutes in disassembly, and usually provide hours more work on the way back. Whether or not these procedures are applicable to your situation, they should make you more aware of the importance of thought and common sense when you do run into "it don't wanna come off" situations, and there is no shop manual to consult.

If you have removed the head assembly, treat it with TLC, as they are expensive. Tag the pushrods to indicate which valve assembly the pushrod came off, and which end of the pushrod was up, in the case of Triumph and some others. This is best done with the inexpensive packages of colored tape found in auto parts supply houses. There are five different colored rolls, and they sell for around $1.00 for all five. Jot down your coding system in your notebook. And do yourself a favor: Don't throw the

1. If you aren't going to be splitting the cases a rag under the piston keeps broken rings and the like out of the crankshaft big end. Saves them for visual inspection.

2. Make sure all the oil is drained out before complete disassembly. At this point a large, clean work area aids sequential storage of parts.

3. Prior to re-assembly clean all the parts and place in position for inspection. Look for missing pieces.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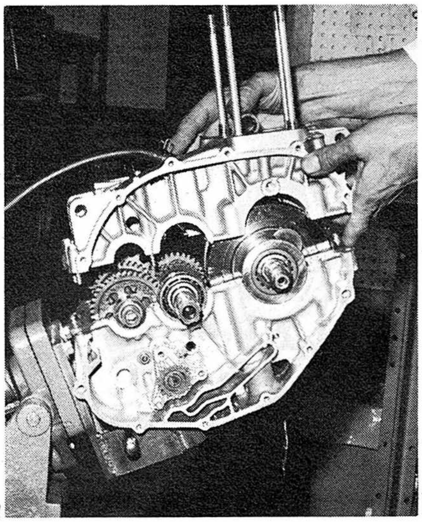
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pushrods in the bottom of a big box, then pile the cylinders and heads in on top of them. Abusive treatment like this causes them to bend, and is a common happening.

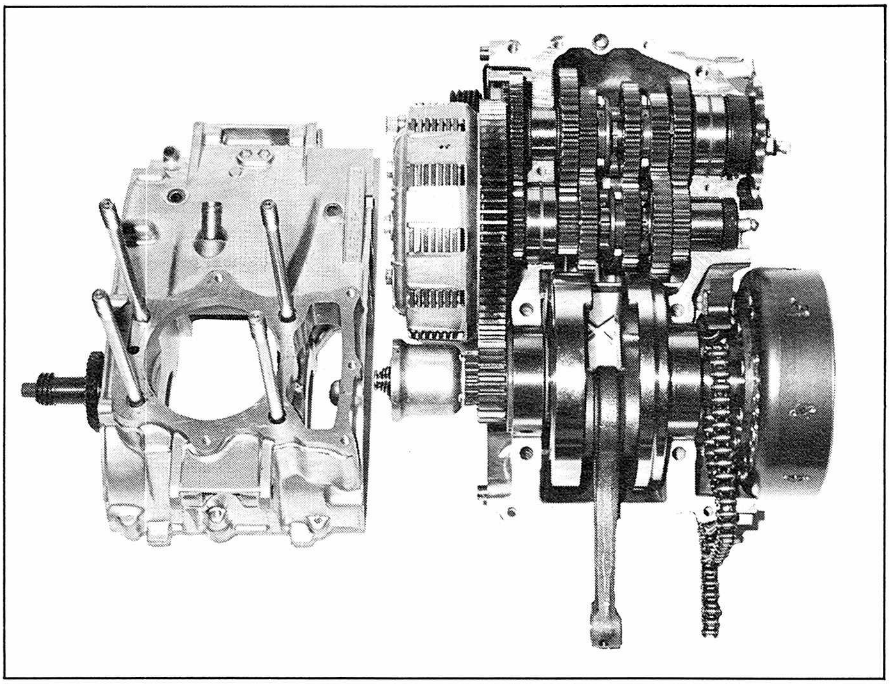
With the removal of the lower motor mounting bolts and brackets, the engine is almost ready to come out. There remains but chain removal. Disconnect the master link, and with the machine in neutral, gently pull on the top run, at the same time feeding the bottom run through to prevent snagging on any projections. Be careful of the brake switch harness which may be in jeopardy of losing a bit of its insulation. Now connect the master link and its clip to either end of the chain. Since your hands are pretty nasty by now, it is as well to clean them and the chain together in the solvent bucket. A thin coat of clean, heavy oil on the chain will discourage rust. Wrap in heavy wax paper, and file it away.

Well, it seems like we finally come to "hoist 'er out"? Sorry about that. There are a couple of minor details to tend to. Clear all tools from the floor area. If there are any oil drippings about, clean them up, or you may look like Willie Mays sliding into your shop area. With a big hunk of unyielding engine cradled around your neck. We daresay such a happenstance could delay the overhaul proceedings.

Humor aside for the moment, safety is an oft overlooked consideration, but one we feel is important enough to bear mention. In view of this, we would recommend you obtain help in lifting the engine out of the frame, especially the "big incher" types. Regardless of the fact that you may be able to lift twice the weight of your engine, four hands are better than two in this case, if for no better reason than to prevent chipping the paint. Note: Check your shop manual before lifting the motor out. Some examples will only come out one way. Others can be lifted out from either side, but the manual will advise you of the easiest method.

DISASSEMBLY

With the engine resting on a bake pan on the work bench, wipe your hands clean, sit down with a cup of coffee and the shop manual, and peruse the paragraphs dealing with disassembly. Take note of any left-hand threaded engine nuts, and identify their location. Left-handed threads are a maker's added insurance against loosening. They are *not* rare. Failure to observe this point, of course, results in rounded bolts and nuts, damaged tools and skinned knuckles. Note and adhere to the maker's recommended sequence. Generally, the procedure goes like this: Small cylinder head studs and nuts come off first. Main headbolts are then undone a bit at a time, working around in the inverse order of torquing. This helps prevent head warpage. If you are removing the heads on the bench, you will need some help in holding the engine. Failing the presence of any volunteers, secure an engine plate to the most convenient (usually front) through bolt. Clamp the other end of the bracket in the vise, and you are ready for some wrench operation.



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With the head(s) detached, collect the associated hardware and clean same immediately. Package and label. Follow this procedure all through the job. Remove, clean, package, label, and put away. You will be rewarded for your efforts when reassembling.

Overhead-cam type machines require special care in their disassembly. Hondas are chain driven, and as a matter of course pose no spec-problems when the well-illustrated manual is consulted and heeded. Some ohc machines use spacers to control the end play and backlash in their geared shaft drives. It is essential that these be refitted precisely as they came out. These spacer shims can be "miked," their thickness and location noted on a simple pencilled diagram. Then they can be placed in an envelope as insurance against loss. The diagram and notations will facilitate reassembly.

Regarding unit construction type engines, the primary drive gear can be removed next. Don't remove the cylinders yet!! Nicks and scratches on the connecting rods will result as the engine shifts to and fro during the goings on of timing gear removal. If your machine is alternator equipped, remove the stator, then the rotor (round magnet attached to the crankshaft.) The stator output harness exits the primary via a hollow bolt extending from the left hand case wall. The normal tendency is to pull the harness wire back through this piece. This works great for a while, but the metal bullet connectors at their wire ends—there are three—will not come through simultaneously. The correct method, of course, is to unscrew the hollow bolt by gripping it on the hexagon portion which is difficult to fit a wrench on at times. Vise grips won't hurt it if clamped lightly on the hex portion. When this bolt is removed (right-hand thread) the wire ends come right on through the larger diameter hole, and the assembly comes off. Stators are delicate, expensive and most likely back-ordered two months, so handle gently. With the crankshaft end nut removed, the magnetic rotor will readily come off, though at times may need a bit of urge, applied with a pair of levers from behind. Place the magnetic rotor inside the alternator stator when stor-

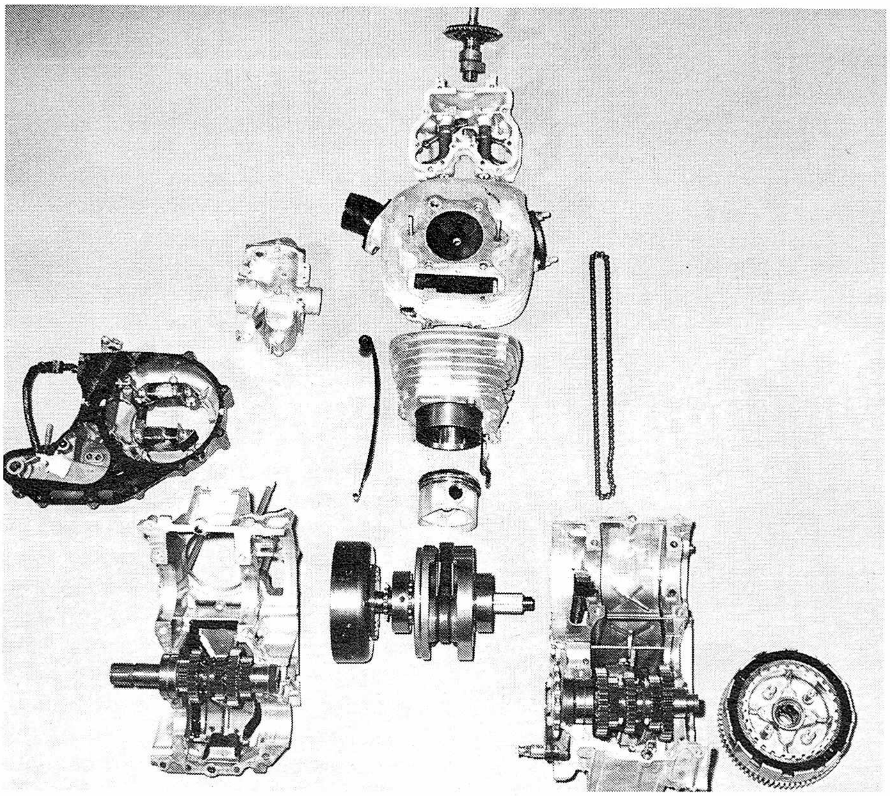
ing. This will keep its magnetic force field from decaying during storage. A weakened rotor field will produce an undercharging symptom. The only way to correct this situation is a new rotor.

The engine sprocket occasionally needs the aid of a gear puller, and care must be used to prevent damaging the crankshaft internal threads.

The clutch assemblies in the type engine we are discussing are simple enough to remove. Follow the directions there. One word of caution (again): Don't ever try to extract the inner clutch hub with anything but the factory puller. This tool is fairly inexpensive and can save you a lot of misery, even if you were to use it only once.

Dismantling the timing side is easy, generally speaking. The late British twin distributors require a special bolt to break them loose from their taper, but a ⅜ × 26TPI bolt can be threaded into the end (following removal of the narrow hold down bolt), given a sharp tap with a plastic mallet or piece of wood, it will break loose from its taper and the timing cover can be removed. Big twin Harley procedure is essentially the same, but a bit less hairy. The timing cover can be removed quite readily, exposing the complete timing apparatus—cam, breather, distributor drive, oil pump drive, etc. With regard to the latter, never remove the Harley oil pump without removing the driving gear and shaft as well. The driving gear is a slip fit on the shaft, retained by a small circlip and a small Woodruff key which transmits the rotational force from the gear to the shaft. It is possible for this shaft to drop through the driving gear, allowing the Woodruff key to fall out. Upon reassembly, of course, the oil pump would be inoperative. Goodbye engine!

With few exceptions, four-stroke engine manufacturers prefer to locate the oil pump on the right-hand side of the engine, driven in one fashion or another by the timing gears. Although the oil pumps are of different types—gear or ball and plunger style, mainly—treatment remains the same. Dismantle, inspect, wash thoroughly in clean solvent, re-assemble after coating the components with oil, wrap and box. The exception to this rule is the BSA oil pump. If the BSA oil pump looks and feels (rotate the tach drive shaft) sound, immerse in solvent, air blast, apply oil and put it away. If you take it apart, you may wind up with a Pandora's Box on your hands.



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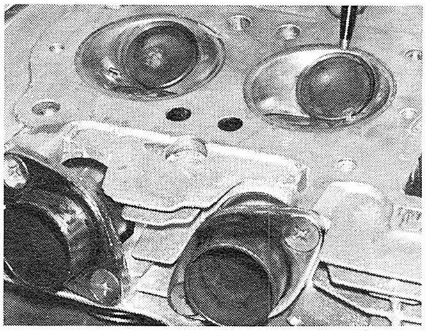

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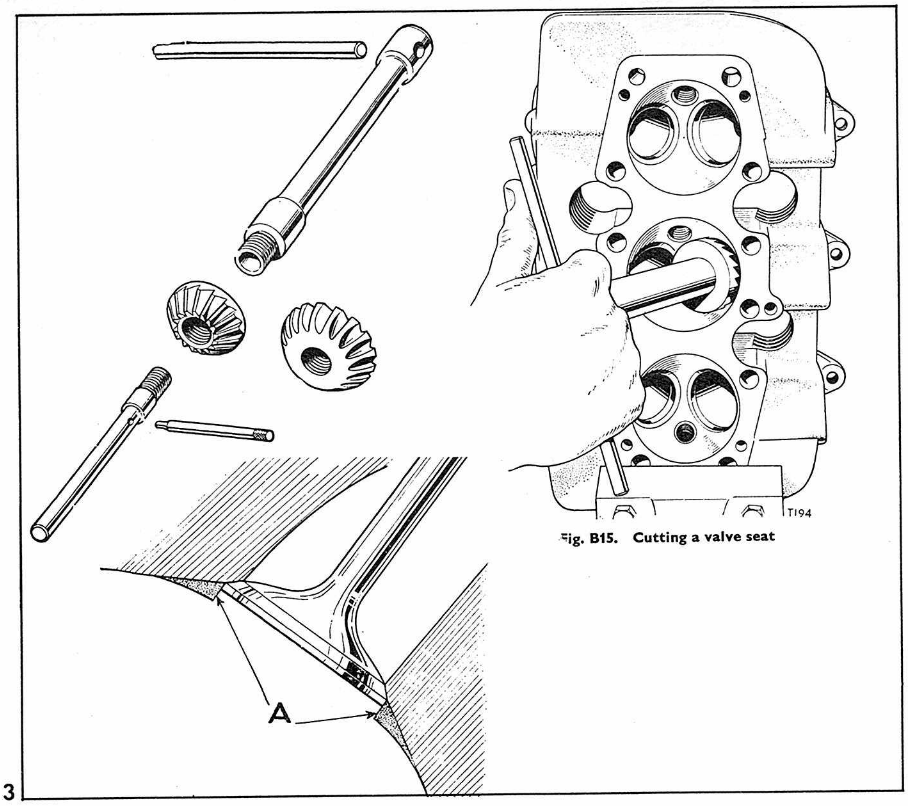
The ball/plunger type oil pumps are reliable, easy to service, and simple to check. Push the plungers downward into the body, holding your thumb over the inlet (upper) holes. Aim the pump away from yourself, for if all is well, oil will enthusiastically shoot from the bottom outlet holes. Maintaining thumb pressure on the inlet holes, slowly withdraw the plungers. When they are almost at the end of their maximum travel, release them, when they should "snap" back down due to vacuum. If they fail to do so, either plunger to body clearance is excessive—replace the whole unit—or there is dirt obstructing the ball valve seat(s), which can be corrected. The ball-and-plunger type pump is inexpensive, but gear-type units can be very costly. The most exorbitantly priced oil pump on the market, however, is a worn or defective one. This type likes to "eat" engines. Don't make the mistake of feeding it.

Timing gear on the British Twins requires special extractor tools to remove. The Triumph cam gear wheels can be removed by use of the Z-89 Cam Gear Puller tool; if the cams themselves aren't going to be replaced, nor their timing changed, they can be left mounted in the cam gears. Don't try to remove these gears without the factory puller. You will damage the casings and bushings. The price of the tool is about $22.00, complete with adaptors, and fits the three-cylinder models marketed by both BSA and Triumph, in addition to all Triumph twins, regardless of the year. The cam gear retaining nuts on these are of a left-hand thread; the crankshaft nut is a right-hand thread. A puller is available to remove the crankshaft pinion gear, but although its use is advisable, it can be gotten around.

BSA cams are also a keyed fit on the gear, and may, like the Triumph, be left mounted in the event the cam is not going to be replaced. The small, usually tight fitting Woodruff keys on the camshaft ends should be removed with the aid of a pair of six-inch diagonal cutters. In removing the retaining nuts from the timing gear, the left-hand side of the crankshaft may be held with an adjustable wrench, on



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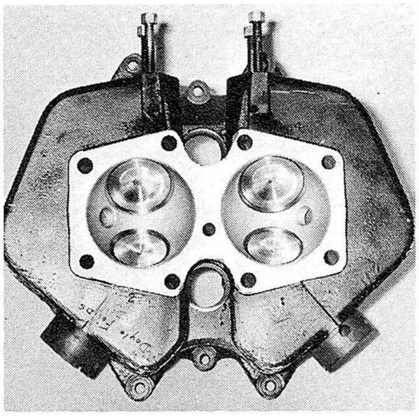
1. Take an inventory of the engine parts before you start repairing and replacing. Sometimes you will find the solution to a mechanical problem came from a missing shim or washer.

2. Visual inspection of the valves can tell you how each cylinder was performing prior to teardown.

3. Valve reseating can be done with special hand tools if necessary. A pocketed valve can mean new seats.

4. Not enough can be said about proper valve and head repair. Cleaning and polishing can add horsepower, improve cooling and insure longer engine life. Crack or flaws will stand out also.



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the splined portion. Check your shop manual carefully and closely with regard to these procedures. If you don't have, and don't wish to purchase the special extractor tools required, the cases can be split, taken to the dealers and the cam wheels removed there.

Now, remove all engine casing nuts, bolts, and studs. It is a good idea to keep them together with their washers by threading the associated nuts loosely back onto their corresponding bolt or stud. Not only will this prevent their confusion later on, but it will also save time when cleaning.

Lifting the cylinders off is a straightforward enough operation, requiring only removal of the base nuts. Keep these together by stringing them all onto a piece of wire. Rotate the crankshaft until the piston(s) are at top center before lifting the barrels. When the bottom of the piston skirt appears at the bottom of the cylinder, position a couple of rags around the rod; if you intend to split the cases, this will prevent damage to the rod surfaces. In the event you are only doing a "top end job," the rags will stop metal particles (such as broken ring fragments) from getting into the "lower end."

Occasionally pistons are seized in the bores, and the barrels refuse to budge. This situation is a bad one at times, and generally calls for experienced hands, as improper technique in removal will cause expensive damage. We assume, however, that you are aware of your own limitations, in addition to the price of a new cylinder assembly. In light of this, we advise the *judicious* use of force. Before using force of *any* nature in this predicament, heat the cylinder barrels thoroughly, using a propane torch on the fins. Try to heat evenly, keeping the flame moving, and working all around the outside of the cylinder. Don't try to heat the inside of the bore. As the cylinder warms up, squirt generous quantities of a penetrating oil, such as WD-40, into the bore. Continue this as you heat, if possible until the top of the piston is completely covered, the idea being, of course, that the cylinder will expand a bit, enabling the oil to seep down and help free the piston. Following this treatment, and before the cylinder cools, run the crankshaft end nut onto the threads, and use a wrench, ratchet and socket, or breaker bar to rotate the crankshaft, freeing the piston. If this effort bears no fruit, have a friend place a piece of suitable wood or other soft material on the top of the piston. A hammer may be vigorously applied to the wood by your cohort, while you exert pressure on the crank nut. Naturally, this is assuming that the piston is in an "after top dead center" position, or you'll be rotating in an upward direction while he's banging down, in which event you'll need to apply your torquing efforts to the left-hand side crank nut, providing it is of a right-hand thread.

It is essential that you avoid using levers, screwdrivers or the like to pry the barrels up. The damage which these items inflict on the machined crankcase mouth surfaces causes oil leakage at this joint. Similarly, hammering on the fins with anything harder than the palm of your hand is not recommended.

With the cylinders removed and cleaned in solvent, examine the bores very carefully, together with the piston skirts. If there are any marks or galling on the areas below the wrist pin holes on the skirt, or above them, on the ring lands, the possibility of a bent rod or excessive crankshaft end play must be investigated. The latter will be discussed in the section dealing with cranks. Rod bend can be detected by the use of a special slotted steel surface plate, or a pair of dead flat parallel bars placed across the crankcase mouth and positioned perpendicularly to the wrist pin. Rotate the crank to bring the bottom of the piston into contact with the bars. Rod bend will be indicated by the gap on either side. An alternative method is to remove the piston, reinsert the wrist pin, and repeat.

One of the leading causes of bent

rods is mishandling during piston removal, since they seldom bend during normal service. To prevent this happening, we recommend these techniques: First, remove the circlips, using small needle-nose pliers, or a screwdriver of the jeweler's type. Pry carefully—if of the spring wire type—partially blocking the wrist pin hole with the thumb of one hand to prevent the circlip springing out and getting lost. Seeger-type clips, (internal locking ring type) are easier to remove: insert a pair of needle-nosed plier tips into the holes in the ears, squeeze together to contract, and pull out.

If there is a possibility the pistons will be reused, mark them accordingly so they'll go back into the same bores. (Note: some pistons are of the offset wrist pin type. These are usually stamped on top with an arrow indicating the front. It is a good idea, regardless, to make a mark on the front side of the piston crown so there will be no mistake in reassembly.)

Now, push on the wrist pin with your fingers; it may be a loose enough fit to come out in this manner. If not, using a propane torch, heat the piston on the top, moving the flame about in a circular pattern. With the piston warmed up, the pin should be an easy push out; if not, have someone support the piston solidly on one side, and a few taps on a drift with a plastic mallet should produce results. Never use more force than is necessary, as hammering can easily bend a rod. Wrist pin removal tools are available for tough cases, but are really seldom used, even in shops.

SPLITTING THE CASES

With the pistons now off, we are ready to split the cases. Check carefully to be sure there are no studs or bolts remaining which would prevent the cases from parting. Triumph twins have two small screws located just below the cylinder base surface surrounding the tappet guide block opening, which must be removed. It is worth mentioning that these screws are left out when using the 48-inch kits marketed by Webco, Inc. as they prevent the larger barrel flange from passing through, and may damage the cylinders.

In most instances the cases will part readily, when held six inches above the work bench (or a wooden block) and brought down sharply, striking the left-hand crankshaft end against the bench. If this doesn't do it, thoroughly heat the left-hand case in the vicinity of the main bearing housing, and repeat the procedure. In no event should a hammer be applied to the crankshaft end. A heavy plastic mallet may be used in stubborn cases, or a piece of wood held to the shaft end, and sharp blows applied to it. Do not use screwdrivers or levers to pry the cases apart; gouges on the seam faces cause oil leaks.

When the cases separate, look carefully for any spacers or shims which may be used to control crankshaft end play. Be certain to note their location, and don't mix them up! Harley-Davidson bearings, which are contained in cages, should be immediately cleaned, coated with grease, and stored in such a manner as to prevent them being mixed or lost. Wash the cases out thoroughly at your earliest convenience.

DISMANTLING THE CRANKSHAFT

Sandwich-type crankshafts, such as the Harley-Davidson and single-cylinder types, which have roller bearing big ends, are no job for anyone without equipment and experience; this chore is best "farmed out" to a competent person. Rod shake can be checked, but should only be done after thoroughly cleaning the "big end" bearing, lest the oil hide a bit of play—which it will. Either immerse the whole assembly in solvent, or use a squirt can containing solvent. Most assemblies call for some side play in the rods (verify this in the manual), but any "up and down" shake indicates the need for servicing. Be extremely cautious when handling the crankshaft assembly, as a hard bump—even against wood—can cause misalignment of the flywheel halves. Squirt fresh oil on the big end bearing if the need for service is not indicated. Leaving the old oil on these assemblies will cause pitting, due to the acid content. Corrosion of these items can be corrected only by replacement. If all is well with the crank, at least have it checked for run-out.

Some later singles have a plain-bearing big end, and these may be serviced very easily, in the same manner as the twin assemblies. Dismantle the rods, taking care to keep the rod nuts and bolts together, and the bottom cap assemblies together with the rod which they came off. It's a good idea to reassemble the rod after removal, screwing the cap nuts back up finger tight.

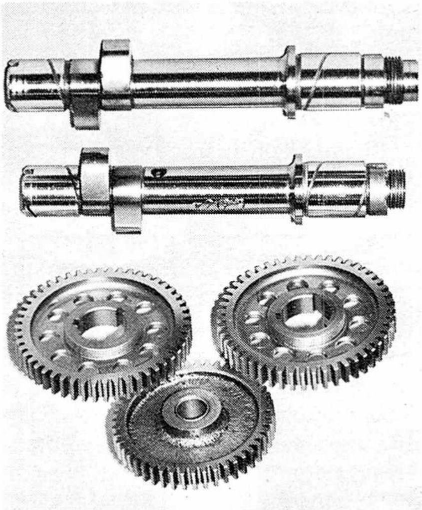
The plug at the end of the flywheels, situated on the right-hand wedge section, can be removed, together with the flywheel bolt which is located between the two journals. The end plug—one on Triumph, two on BSA, may be center punched. Drill the center punch marks with a ⅛-inch drill bit to a depth of ⅛-inch. Rarely, if ever, will a screwdriver loosen them; the use of an impact wrench is called for, if only the hand type, together

1. Pay particular attention to the condition of the valve train. If many miles are on the machine camshaft(s) and drive system will wear out.

2. Retaining clips for the piston pin must have good spring tension and fit in their grooves. Remove all carbon and clean the ring grooves.

3. Check inside the piston for signs of fatigue or small hairline cracks if they are to be reused. Clear oil holes.

4. Replacing the small end bushing can be done with a socket or large tube, nut and bolt and new bush. New bushing drives out old while seating itself. Can be done in vice also.



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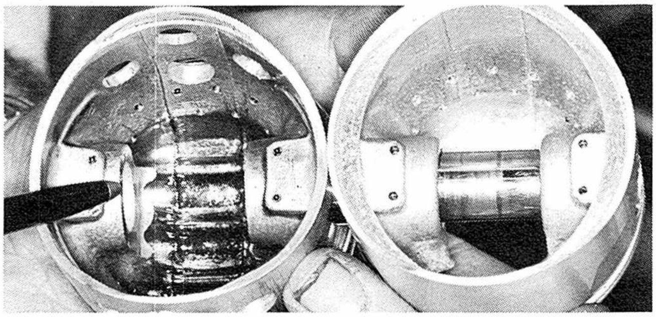

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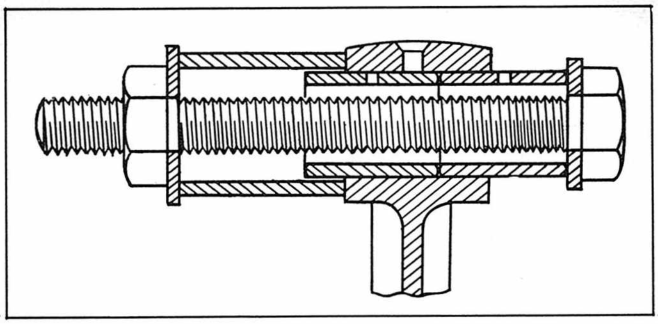

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with a "drag link bit." The sludge trap within will, no doubt, be loaded with some nasty looking muck; and can be withdrawn by use of a hooked rod or a large "E-Z out" extractor. Clean every last bit of sludge out of the trap, but don't reassemble as yet, for if the crankshaft must be ground to an undersize, and undersized rod bearings used, it will have to be cleaned again to remove metal particles, and finally blasted through with air pressure, along with the oil passageways.

MEASUREMENT AND INSPECTION

All moving parts must now be checked closely for wear. This is where the inexperienced mechanic frequently comes unknowingly to grief, and often re-uses parts which "don't look too bad," but will cause knocks and rattles. The crankshaft journals should be carefully miked, working around the journal to be sure it is not out of round—a thousandth or so may be all right, but go by the manual. If you are measuring yourself, check and double check all readings. You will at least need to know what size the journals currently are, so you can obtain the correct size rod inserts—don't reuse the old ones regardless of what they look like, it is poor economy. In the event machining of the journals is indicated, expect to pay about $10.00 to $15.00 for the service. BSA twins and singles have a bushing fitted on the right-hand side of the crank. The diameter of the journal at this point should be measured; if need be, it too can be ground to an undersize, though this is not a prevalent condition until the machine has seen many, many miles.

All bushings in the crankcase should be checked, paying careful attention to the BSA right-hand main bushing. Wear at this point will cause a noisy engine, and poor oil pressure. All measurement readings should be written down as they are taken, and compared with factory specifications.

Cam bushings should be checked with a telescopic snap gauge and micrometer, the cam bearing journals checked, and the difference will be the clearance. Wiggling the cam inside the bushing is a poor method of checking, as even a good fit will show some sign of "wiggle." Ball and roller bearings should be examined for roughness and pitting. Wash them in clean solvent, holding them in a horizontal position while rotating the inner races back and forth. Finally, air blast them, and if they are all right, apply a coating of fresh oil.

Camshaft journals should show no signs of galling or scoring; the lobes should show no signs of "flats," which would call for replacement. Tappet feet may evince slight signs of wear, but any cracks in the material on the feet again indicate the need to replace. Check the tops of the tappets—if they are ball shaped (e.g. Triumph, BSA) look for flat spots, as even the smallest of these will wreak havoc with pushrod adjustments later on. Harley-Davidson favors the roller tappet; feel for any up-and-down play, evidence of which necessitates replacement of the bearing. The tappet itself is reusable providing there is no serious wear or damage to the cupped tops. Place the tappet in the guide block, and feel for "slop." The clearances here are only .001-inch or so (check the book). Accurate measurement requires the use of an expanding ball type gauge or a telescopic snap gauge and a one-inch micrometer. Measure the tappet bore in the guide block, and the tappet stem. Overlooking these items will mean differences in the cam timing, and a noisy, inefficient motor.

Working our way up, as it were, examine the pushrod ends for chipped cups, cracks, flat spots (if the ball type), and bend, which may be determined by rolling the pushrod on a dead flat surface, such as a piece of glass. Needless to say, any sign of the above mentioned deformities will require replacement.

The cylinder barrels must be measured with an inside micrometer. Measure the base of the cylinder first, in the front to rear plane, i.e., at a 90-degree angle to the wrist pin, since this is where maximum wear occurs. Note the reading at the bottom. Invert the cylinder, and take a reading just below the ridge at the very top. Read again, ¼-inch down from that, writing the readings down as you go; repeat the readings every ¼-inch for the first inch, as this is the area of maximum wear in the cylinder. Subtracting the bottom reading from the maximum diameter read at the top gives the amount the cylinder is "tapered." Allowable taper varies from make to make, so consult your manual here. Measure the piston skirt with an appropriate outside micrometer at the points shown in the photos. Measure the inside micrometer with the outside micrometer, to give the piston clearance accurately. Subtract the skirt dimension reading from this, and the result, of course, is the clearance. Whether or not the old pistons can be reused, or if boring is necessary, may be determined by consultation with your private "expert," namely the shop manual. Remember that excessive piston clearances cause the piston to tilt at top center, cocking the rings and exposing them partially to the fury of the combustion.

You should be placing all the worn out or bad parts together, and listing them as you go along. Oversized pistons are obtainable at your dealer, and if boring is needed, you will need to take the new pistons together with the cylinders to the machinist you select. It is advisable to take everything that needs machining, e.g., crankshaft, cylinders, heads, and so forth, together. This will save you legwork, a necessary and time consuming part of any overhaul.

Try to obtain all your parts in one trip. You will need your list for this to make matters easier for you and your dealer's parts man. Don't forget to write down the year, model, and

serial number of your machine, to enable them to help you better. It is a good time to check on any possible modifications while you are parts shopping, so you may update your engine, thereby adding to the reliability of your machine. Take all the engine seals and special lockwashers with you, so they may be correctly replaced in your parts order. It is inadvisable to reuse these items, as their cost is not high. Don't forget to obtain all new gaskets, cylinder head gasket included. Most manufacturers provide a "Full Overhaul Gasket Set." Jointing compound can be obtained from your dealer, or he can recommend the right type for use on your motor.

BUSHING AND BEARING REMOVAL

If your measurements have indicated some bad bearings or bushings which will need to be replaced, you may have your dealer perform this chore for you. If not, the following instructions will tell you how to do it.

In the case of "blind end bushings," such as the timing cover bushings in Harley-Davidsons, and the left-hand cam bushes in the BSA and Triumph, a tap will be needed, together with a suitable bolt of the same thread. These are usually obtainable from used tool stores, surplus outlets, etc. Tap the bushings to be removed, heat the engine crankcase in an oven at 400 degrees for about 20 minutes. The hot case can be placed on the bench, and the bolt threaded into the bushing. Clamp the head of the bolt firmly in your bench vise, and, using a plastic mallet, tap the case away, leaving the bushing and bolt in the vise. Repeat as necessary. The new bushing, which can be placed in the freezer compartment of your refrigerator while the case is heating, can now be driven in carefully. Be sure to line up the oil feed holes. If the old bushing was a loose fit in the case, some Loc-Tite "Bearing Mount" can be used to coat the outer diameter of the new bushing prior to installation. This will prevent the new bush from becoming loose in its housing.

Ball bearing mains will either fall out or tap out very easily once the case has been given the heat treatment. The outer races of the two-piece roller style bearings, however, will require drilling three holes in the case, 120 degrees apart, and in line with the edge of the race. After heating, a pin punch can be applied alternately to the race through the holes, working it out in easy stages. At any rate, under no circumstances should you ever drive a bearing or bush out of a cold case. You will gall the housing and cause looseness between the bearing and the housing. If this is already in evidence, apply Loc-Tite Bearing Mount, and keep your fingers crossed. Peening the metal at the bearing edge will also help retain a bearing in a loose housing, but we don't recommend this on a good fitting setup.

A frequently overlooked bushing in the unit construction engines is the fourth gear bushing in the transmission. The gear must be removed to replace this bushing, but if it is worn, it is advisable to do it now. This is the one that causes all that oil to drip out of the transmission housing when the motorcycle is parked on the side stand.

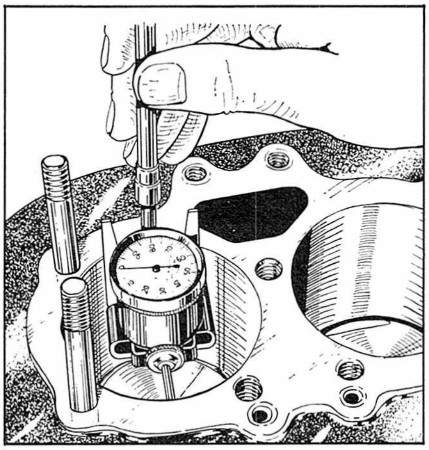
Pre-1963 Triumph motorcycles have an oil feed bushing in the timing cover. It should be checked, and replaced if necessary. Overlooking this will cause lower end problems and "wet-sumping," which means oil blowing all over the place due to an overloaded lower end. One result of this is usually hours spent trying to find out what's wrong with the "darn oil pump," when the only thing wrong with the oil pump is that it just can't keep up with the "flood" from the high pressure at the bushing. These bushings are supplied in undersize, allowing the nose on the right end of the crank to be machined to suit. Alternatively, the bush can be reamed out if the crank end is in good shape.

Having replaced any bushings, consult the manual. They may have to be "line-reamed," a dealer operation. These reamers are very expensive. Cam bushings in practically all engines require line reaming after replacement. This assures proper clearance and alignment and prevents stress.

When dealing with the clearances in your engine, don't be taken in by the "loose ones go fast" bit. You are not building a racing machine (presumably), and loose fits will only result in a noisy, short-lived engine. However, follow the factory standards. You will obtain no more out of your motor than you put into it.

CYLINDER SERVICING

If your cylinders require boring (prices for which range from $5.00 to $10.00 per "hole") you may want to finish hone them to suit your own taste. Boring usually leaves a razor sharp edge at the top of the barrel.



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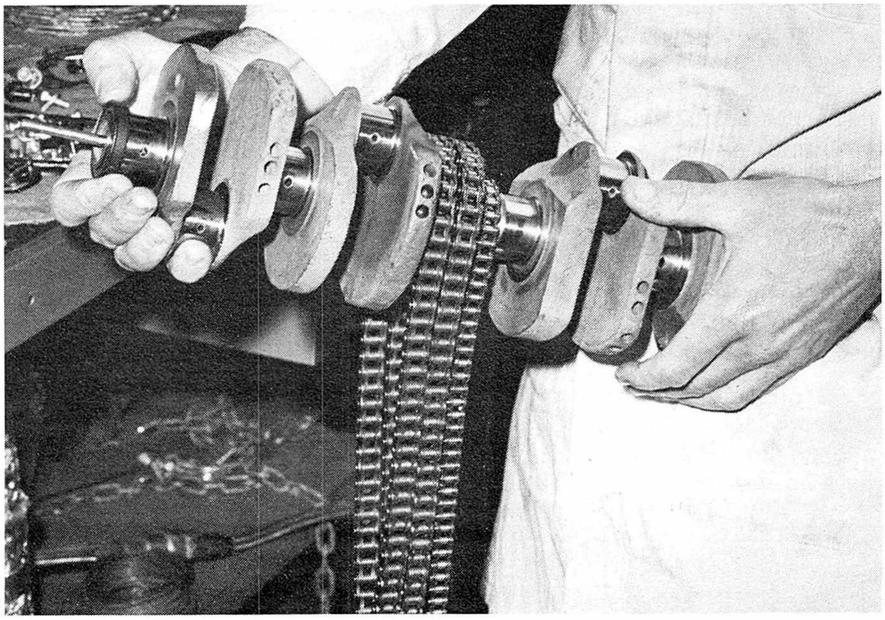

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This must be dressed off with a small file. Left on, it will cause pre-ignition, as will any sharp edge in a combustion chamber.

Honing can be done with a medium to fine grit set of honing stones. Don't clamp the cylinders themselves directly into a vise. An old metal bracket, or suitable jig, should be bolted to the cylinder base stud holes, or other convenient place, and then clamped into the vise. Use kerosene or solvent while honing, keeping the cylinder as wet as possible. Use steady even strokes, about 50 per minute, and keep the hone moving up and down while it is in the cylinder. When stopping to check, always stop at the end of a stroke, with the honer blades partially protruding from the cylinder. Now they can be squeezed together with one hand, and the assembly pulled out with the other. Never drag the stones out of the barrel. A nice, even cross-hatch pattern should be left on the cylinder bore, with no deep scratches in evidence.

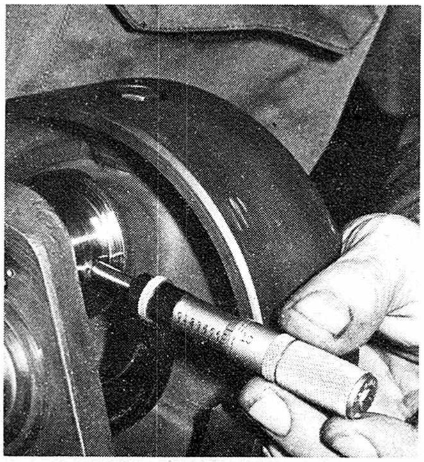
After honing, wash the cylinder thoroughly in hot soapy water. Cleaning in solvent after boring or honing only serves to embed fine metal particles in the bore. After thoroughly drying the cylinder with a soft cloth, smear or spray a thin film of oil on the new surface.

Before putting the cylinders away, check the ring gap. This is done with the new rings. Place one at a time in

1. Plan on needing precision measuring instruments. An inside micrometer will be required to measure cylinder bore size for piston fit.

2. Crankshaft care is critical. Keep journals covered with oil film to protect from damaging corrosion.

3. If you aren't sure of what you are doing take the crank to a competent dealer for repair. He will have all the right tools and inside dope. Hold tolerances recommended by factory.



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the base of the cylinder in which it is to be used. Square up the ring in the bore using the bottom of the piston. Check the gap with a feeler blade. Your service manual will give the recommended ring gap, but a good rule of thumb is to use .005-inch for every inch of bore. If the gap is less than desired, a thin file clamped in a vise will rectify matters quickly. Hold the ring carefully between the thumb and forefingers, press gently to the file, and stroke. Cut on one stroke, and release pressure on the back stroke. Check frequently in the bore, and try to keep the ends as even as possible. If you go a bit too far, don't worry; loose end gaps are far better than tight ones. Clean the ring ends of filings before placing in the bore to check. Keep the rings sorted to prevent their being eventually mounted into the wrong bore. And be very careful when handling the rings, particularly the oil control rings. They are brittle and can break very easily.

In the event you are going to use your old pistons, they should be decarbonized, and the ring grooves cleaned. The best way to do this is to have them "glass blasted," or "vapor honed." Both terms describe the same process, which is similar to sand blasting, but incorporates the use of minute glass beads. This process is inexpensive—about $1.50 per piston—and will leave them in "like new" condition. The vapor hone treatment leaves no gouges in the critical ring grooves, nor scratch marks on the piston crown. Lacking this, an old ring can be used to clean the ring grooves of accumulated carbon. Be sure you don't damage the ring lands by taking metal along with the carbon. The old wrist pins also should be checked in the event they are going to see further duty. If they are "blued" in the areas where they enter the piston, they should be replaced, as this means they are soft.

The wrist pin bushings in the rods can be checked at this point, by use of "feel," or preferably, a telescopic gauge and micrometer. Measuring their inner diameter, and comparing to the measurement of the wrist pin will give the clearance. Ordinarily, this is in the vicinity of .001-inch or so. Any "rock" felt on the wrist pin when placed in the rod, would indicate the need for replacement.

Replacing wrist pin bushings is a job best left to the "shop," but "if you gotta," the procedure is thus: Mount the rod body in a vise, wrapped tightly in a rag. With the new bushing ready to go, obtain a socket, which will fit around the wrist pin bushing, and more than accommodate its length. Run a long, threaded bolt through the socket. Heat the end of the rod well with a propane torch; when warm, position the wrist pin in the rod bushing, so its end is just flush with the edge of the rod bushing. Place the new bushing on the portion of the wrist pin which is protruding. Position the socket on the other end of the rod, being sure its edges are not going to foul the wrist pin bush as it comes out. Run the bolt through the socket, wrist pin and bushings, so that its end protrudes beyond the new bushing. Place a flat washer over the bolt end, thread a nut onto the bolt end, and begin tightening the nut down on the bolt. It will force the new bush in, and the old bush out into the socket portion. The wrist pin will maintain the alignment of the new bushing as it goes in. Wrist pin bushing removal tools may be purchased at your dealer, and are reasonably priced.

After fitting the new bushing, final reaming may be necessary, along with drilling a hole at the top—in most instances—to assure lubrication. Most auto machine shops can hone the pin bushings to a precise fit for a reasonable charge.

SERVICING THE CYLINDER HEAD

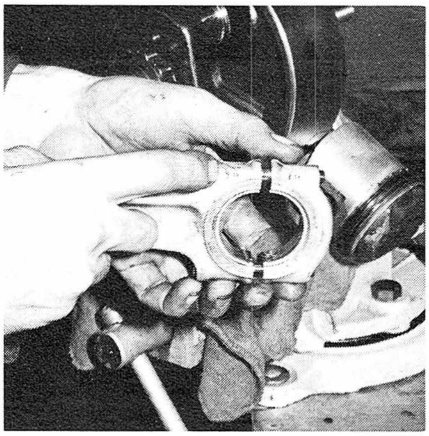
The most important performance component of the engine, is the cylinder head. Regardless of how well done the engine is from the "head gasket down," the condition of the head, and the manner in which it is serviced can mean the difference between a smooth running or poor performing engine. Cylinder head maintenance is where most inexperienced mechanics fail. Haphazard work will result in poor performance. Since the head, per se, is relatively uncomplicated, it pays to be attentive to every involved detail. To start things off correctly, a tool can be fabricated out of some ½-inch round stock and an old spark plug. Knock all the guts out of the spark plug body, taking care not to damage the threads. Place the tool into the degutted plug body, and weld up. These tools are also available over the counter as an accessory item. A valve spring compressor—$6.00—is a must. The type marketed by Triumph-BSA dealers will take care of

most heads, including the Harley-Davidson, though H-D has their own, more expensive—but better—unit.

Thread the head holding tool into the spark plug hole, and clamp the end of it tightly in a vise. Never clamp the head in a vise or you will damage it. Position the compressor tool with its yoke on the valve collar, its bolt point on the valve head. Tighten it up till it is firmly in contact with the valve collar. Slowly tighten a bit more, and observe the collar to stem area. If the tool seems to be tightening with no indication of the collar compressing, assist matters with a sharp whack on the end of the compressor tool. This should free the keepers and collar, and the tool can be screwed down further till the keepers have enough space to come out. If you were to continue compressing the tool on a stuck collar/keeper assembly, you would bend the tool arbor.

A pencil magnet is handy for withdrawing the valve keepers, once the collar and spring assembly is compressed. Use small strips of plastic tape to keep the keepers paired. With the keepers withdrawn, release the spring and collar assembly, withdraw the valve, and repeat the procedure on the other valves. When all the valves have been removed, inspection and measurement may be immediately undertaken. Examine the valve stems for galling, and measure them with a one-inch mike. Most British valves are .309-inch on the stem. The ball gauge must be used on the valve guides, although extreme wear can be felt by wiggling the valve in the guide. Mike the ball gauge, and subtract the reading from the valve stem. Consult the manual to see if you are within factory tolerances. If the clearance borderlines on the maximum allowable by the factory, replace the worn valve guides and the valves if necessary. By the time valve stems are worn any appreciable amount, you can count on replacing the guides. Now examine the valve faces. They may need to be machine faced. Be sure there is enough material on them to allow facing without leaving a razor edge. If not, replace the valve(s).

Having determined what will be needed partswise, the best way to clean the head is the glass beading (vapor honing) process. In lieu of this, chip the heavy carbon deposits away carefully, with a screwdriver blade.



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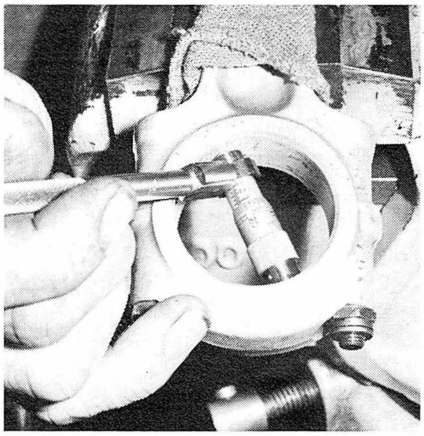
Try not to gouge the aluminum. Finish the job with a soft wire brush and drill motor. Clean the ports well, and particularly around the valve guides. Additionally remove the carbon from that part of the guide which protrudes into the port. If you try to drive the guides out without doing this, you will ruin the valve guide bore; just like driving a rat-tail file through.

Place the clean head in an oven, give it the 25 minutes at 400 degrees routine, then remove. You will need a valve guide punch to drive the guides out, and the preferred method is to have someone hold the head with heavy rags or welder's gloves while you drive the guides out. This will prevent shock damage to the spark plug threads—where the head held in the vise with the tool. The new valve guides should be installed immediately. Having them on ice or in the refrigerator while the head is heating will help matters. However, if the old valve guides were very loose coming out, oversized valve guides will need to be fitted. If the old valve guides were already oversized, they will of course need to be replaced by ones with a larger outside diameter. Oversized valve guides may be distinguished by small rings machined into their upper section. As a rule, each machined mark indicates .001-inch oversize, but in some instances represents .002-inch over. Your dealer can advise you on this.

New valve guides necessitate grinding the valve seats to true the seat to the guide, making them concentric. This requires an expensive hard seat grinder, which relegates this chore to a shop.

With the seats reground, and the valves faced (or replaced with new ones) the head may be secured in the vise with the head tool. Use valve grinding compound, and lap each valve to its seat individually. Apply



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1. Connecting rod and cap must be kept paired. They should be numbered or punched for coding. If not plan on doing it. Identifies side of cap.

2. Before replacing babbitt place cap on rod and torque nuts to factory specs. Measure with inside mike.

3. Keep your working area spotless during crankshaft work. A torque wrench, preferably reading in both foot and inch pounds, is an absolute necessity.

4. Before assembled pre-lube all parts with oil film. Pressed together crank assemblies will require truing to eliminate excessive run out. Will require centers or 'V' blocks.

small dabs of fine grade compound to each valve face in turn, place the guide in position, and with a lapping tool, rotate in a back and forth manner to cover 180 degrees. If, for one reason or another the valve lapping tools available don't work out too well for you, place an eight-inch long piece of PVC or rubber tubing onto the valve stem and, using the flats of your hands to oscillate the tubing, continue with the lapping process. Remove the valve now and then, clean the compound off with a rag, and observe the seat. A thin grey line should appear, and should be even throughout. Continue lapping as needed to obtain this effect. As each valve is lapped to its seat, label it to prevent confusion. After all of the valves have been lapped in this manner, wash all traces of grinding compound out of the ports, and air blast dry or use soft cloth for the purpose.

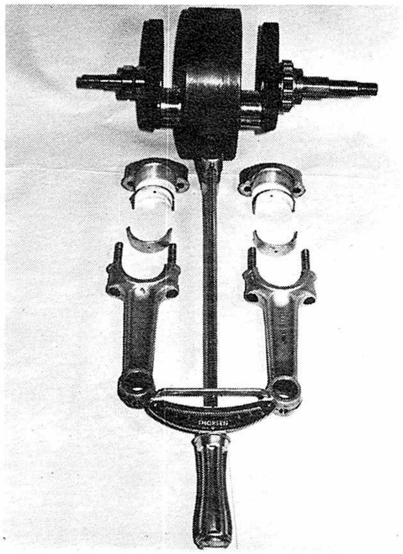
Valve spring pack, or the seated height of the valve spring, which controls its tension, is normally thought to be in the realm of speedwork. However, it is just as important to the stock motorcycle.

Install each valve, in its turn, and assemble the collars and keepers, using the inner spring only. British motorcycle owners can use a carburetor slide spring for the purpose.

Measure the distance between the underside of the upper collar, and the upper face of the bottom collar. Compare this to the data in your manual. If it's not contained in the manual, consult your dealer. If the "pack length" is excessive, check the hole in the valve spring collar where the keepers abut. If it is worn, or enlarged, it will need to be replaced. Generally, the surplus height is from the seat having been ground. Valve spring shims of the appropriate thickness can be obtained to correct the situation. In the case of Triumph-BSA, the discs from Bendix bicycle brakes turn the trick. If you are fitting an oversized valve to compensate a pocketed valve seat, you may be a bit shy on spring height. The difference will have to be machined off the valve stem, where the keepers abut.

Regarding the matter of valve springs, these are certainly due to be replaced by the time the machine needed an overhaul, but their tension can be checked on a spring tester. The book gives free length specifications on the springs, but this is by no means a definite indication that they are good. If in doubt, replace. The best bet for new valve springs for British models are the S&W, marketed by Webco. They are a progressive-wound spring, and must be installed with the close wound coil to the bottom. Additionally, they may require a valve spring pack different than stock, in which case shimming is in order. Specifications for the model are included with the springs.

After determining the appropriate shimming required, assemble each valve in turn. Don't neglect to lubricate the valve stems. With the head all together, wrap it carefully, and store it away from dust, grit or dirt.



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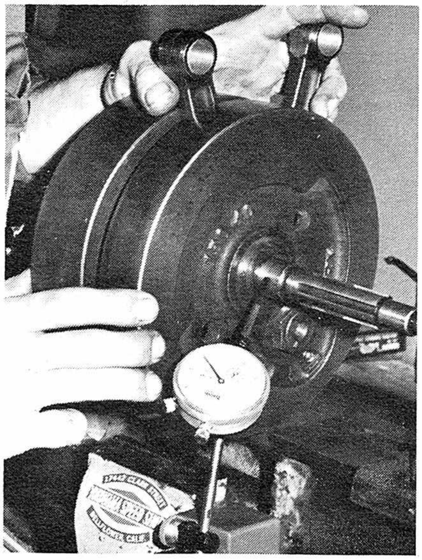
CRANKSHAFT ASSEMBLY

Having ascertained the needs of the lower end, the flywheels hopefully are ready to go. If they were machined or balanced, they will need to be super-clean. The new rod inserts should be at hand, and ready to go. If there were any nicks or scratches inflicted on the rods, they can be polished out. The rod nuts and their special nuts should be in good shape. On older models with many miles, they are inexpensive to replace considering their importance. Place the new inserts in the upper and lower rod sections. There is a small recessed portion in rod and cap, with a correlating raised section on the back of the insert, to retain these in position. The notch on each should be opposite the correlating notch on the mating portion.

Carefully, and with clean hands, smear a thin film of heavy viscosity oil on the journal. Place the rod bolts in position in the upper rod, taking note of the offset heads at the top, which must be positioned at 90 degrees to the rod. Before placing the upper section in position on the journal, make a final check of the rod insert. Is it seated properly? Is there any lint or dirt specks on it? If so, rectify. Place the rod down on the journal. Hold it firmly in position with one hand, bring the bottom rod cap and insert assembly into position. These usually have dots, to ensure they aren't put on wrong. Make sure the section with the center punched dot aligns on the same side as the mating dot on the aluminum upper portion of the rod. You may have to tap the cap gently with a plastic mallet as the bolts are a snug fit. When it makes contact with the journal, thread the nuts onto the cap bolts. Ratchet them down to about five ft.-lbs. of torque: just "wrist tight." There are two procedures of assembly from this point to assure correct tension. One is to "mike" the bolt stretch to a .004-.005-inch figure (check your manual) the other is to use a torque wrench. Torque each side five ft.-lbs. at a time. After each increase, check the rod to be sure it is still rotating quite easily on the journal with no sign of "drag." From 28 to 32 ft.-lbs. will take care of most. With the rod finally torqued, it should still be quite free to rotate on the shaft (journal) with no drag other than the minute amount caused by the heavy lubricant. If the rod locks at any time during the proceedings, remove it and check the journal all around for nicks or other abnormal markings. The rod inserts also can possibly be in error. Example: Undersized inserts for a standard journal. Don't ever file the rod caps or be tempted to "scrape" the insert bearing; you will come to grief. Hopefully, all will be well, and the procedure may be repeated on the other side. Reassemble the cleaned sludge trap. Use Loc-Tite on the flywheel bolt between the rod journals. Be sure you torque this bolt to the recommended figure, normally circa 45 ft-lbs. Replace the sludge trap plug. If the slot in it is gouged or in bad shape use a new one, to make future removal easier. Impact it tightly, and center punch it at the seam to prevent the possibility of it coming loose at any time.



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Now is the time to install any seals which mount in the crankcase. A slight chamfer on the aluminum case edge will expedite installation. In case the seal is of the lipped spring type, assemble with the spring facing the pressure side, or the highest pressure side. Left-hand crankcase, main seals face the lower end and crankcase, as naturally it contains far more pressure than the primary. If you have knife- or file-chamfered the seal housing edge, you will have to clean out the metal filings, then wipe or air blast (the latter preferable).

Before assembling the crankcases new bearings and/or races will have to be installed, a process which is practically the reverse of dismantlement. This of course, assuming that you haven't already done so. Place the left-hand case down, and insert

only the crankshaft. Run three or four through bolts in and tighten securely. Now, check the crankshaft end play.

The manual gives tips on this. A simple jig can be made up to accomplish the job. Excessive end play can be measured, noted, and corrected by the use of an appropriate size shim, placed between the flywheel and the crankcase. Insufficient play may necessitate the removal of an existing shim. This is common with BSA, especially when a new right-hand main bush has been fitted. Triumph doesn't ordinarily require it, but; if the need is apparent, do it.

Harley-Davidson lower ends are best farmed out to a competent dealer with the equipment to do the job. You can, however, change the pin bushes if necessary. Even most dealers farm out crucial machine work, so don't try to do a job yourself if you don't have the experience or equipment.

Harley-Davidson end play should always be checked. There is no guarantee that it will be all right as is, or that it was correctly accomplished in the course of the last overhaul. Shims adjust H-D end play also.

The clean, left-hand engine "half" (case) should now be laid flat, and preferably supported in a crude 2x4-inch wood block jig. Coat the seam with jointing compound. There is no gasket on this junction. Don't coat the compound on, use sparingly to obtain a thin, even film on both surfaces. This will prevent "squish" dribbles on the inside of the case.

Harley bearings should be assembled with heavy grease, and, noting the location of the thrust washer, placed in the crankcase. Insert flywheels, assemble the right-hand bearing, lube, and install the left-hand case. Assemble through bolts and tighten.

Assemble British models in the same manner, with the exception that the cam(s) must be installed. Triumph and BSA have a crank breather disc and spring combination, which is placed at the bottom of the Triumph intake cam, and in the single left-hand cam bush common to the BSA. The spring mounts inside the disc, and the flat part of the disc faces down, toward the primary side of the bike. This disc has two "ears" or tabs, which engage slots in the camshaft to provide drive. Squirt oil into the bush and on the cam. Insert the cam, with the driving slots aligned with the disc's ears. In the event the cam is still attached to the camwheel or sprocket, rotate the latter to achieve a close "eyeball" alignment. Lubricate the bearings, airblast all the oil passageways, and check the air tightness of the sump pickup tube in the right case (blow through the bottom of the tube, cover the hole at the oil pump mount where the pressure is blowing out, then suck on the tube. It should be positively air tight).

Assemble the right hand case. We should mention that late ('63 up) Triumph owners, who may have fitted a cam of more radical specs, should ensure that the exhaust cam contains the small slotted disc which drives the tachometer. If not, fit one. They are very inexpensive.

With the right-hand case in position (a slight assist with a light plastic mallet may be necessary) tighten the securing bolts immediately. If the upper end is not to be assembled right away cover the crankcase mouth.

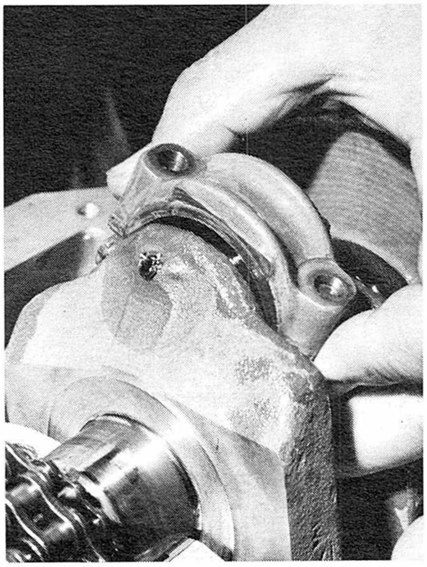
CYLINDER ASSEMBLY

Check the rings before assembling. Most have a tapered, or beveled inside edge, which always faces the top. This taper, or bevel if you prefer, allows high pressure combustion gases to pass behind the ring, and force it outward against the cylinder wall. Chrome rings, when provided, are fitted to the top land alone.

Piston assembly is the reverse of removal, including heating the piston when necessary. The wrist pin bush, piston bosses, and pin should be smeared with oil before assembling. If you are replacing the pistons, and using a set of forged aluminum ones, it is imperative that the wrist pin clearance in the pistons will be checked; these call for a loose fit. Check the specs which came with the piston assembly; they will detail the involved elements. In assembling the cylinders, you should use ring compressors. Here are a few assembly hints: Space the ring gap openings 120 degrees apart. Place the top ring gap at the furthest point from the two main sources of heat, namely, the spark plug and the exhaust valve. In the Triumph, as an example, the top gap faces the inlet pushrod cover. BSA top rings face 7:00 o'clock on the right-hand side, and 5:00 o'clock on the left-hand side, looking down at the bores. The theory is to keep these gaps to the coolest part of the cylinder. Despite the "rings spinning" theory, this method has worked well for us over the last 10 years. Lubricate the piston skirts, and install the base gaskets, lightly coating them with grease. Install cylinders.

The rest of the reassembly is straightforward, and outlined in your shop manual. With your bits and bolts clean and assorted, you should have a minimum of trouble. The best policy in reassembling is this: Don't hurry. Timing side may be assembled as per directions. Triumph owners can benefit immensely from "degreeing the cams in," or "cam tuning" as it is called. This process enables the Triumph owner to precisely set the timing on both cams, via the three keyway cam gears make this possible. Consult your dealer.

In reassembling gears to keyed shafts, be certain the gear or wheel will fit with no problem. Due to "pinch," the back edge of the key slot may have to be relieved a bit with a small file. Keys should fit well in the



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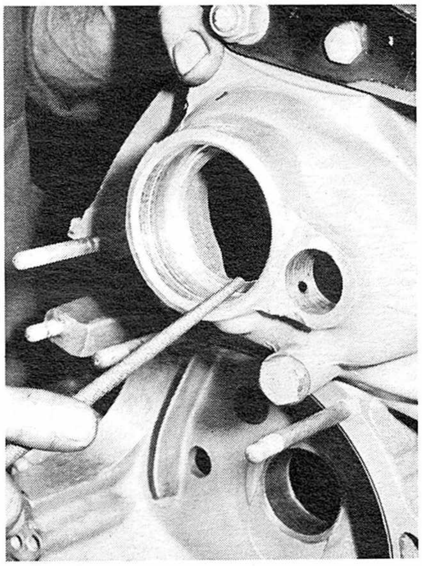

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shafts, and be tapped down firmly into position. If they are hard to get on, lightly sand the edges of them, as the more tight fitting examples tend to expand when initially removed.

PERFORMANCE PARTS

Pistons: When fitting higher compression pistons in place of stock, run the piston clearances a little looser. Higher compression means more heat and heat causes seizure. The timing must be retarded because combustion efficiency is higher, and combustion is quicker. The object is to reduce the negative work on the piston, as well as provide maximum combustion. It is especially important to time both cylinders, or at least check the timing on both. If one is correct, the other advanced, the advanced side can cause just as much trouble as if both were advanced.

Valve-to-piston clearance will have to be verified. This is important, particularly if the cam profile has also been changed.

Carburetion has to be enriched to accommodate the higher compression. A lean fuel mixture causes seizures and "holed" pistons.

1. Engines like the Honda Four necessitate installing the crankshaft in the engine prior to rod replacement.

2. Replace all case bearings or bushings while the engine is apart. Cheap insurance. Smooth all cavities where burr may occur when old bearing is pressed out. Clean filings out of cases.

3. Be sure that oil passage holes are in perfect alignment prior to installation. After pressed in clean out passages and de-burr. Pre-oil bushings.

4. Double check work by torquing to factory specs and checking clearance with Plastigage. After tightened make sure assembly will turn by hand.

Cams: Longer duration, higher lift cams are going to require head work. The valve train should—and in cases must—be lightened to reduce inertial loads. They also require different spring pack techniques, to increase valve spring control. Additionally, clearance must be checked between the lower side of the upper collar, and the top of the valve guide. There is a possibility of the collar striking the guide; this will bend pushrods, and break rocker arms. Different pushrod adjustments will undoubtedly be called for. A free flowing exhaust system, of the right length and diameter will be essential, or the increase in valve lift and height will be wasted, if not a detractive factor. "Bigger" cams can require larger ports, valves and carburetion before they can become worth their salt. Remember that with modifications of this nature, you are narrowing the usable power range, and placing the power band further up in the rpm range. Factory cams of late model machines generally provide all the power you will ever be able to use. Follow the directions in the manual and this article, and you will have a superbly running machine.

FINAL ASSEMBLY

The carburetors should be boiled clean, reassembled, and installed, with preliminary adjustments. The oil tank, which should have been flushed, can be mounted, and the correctness of the oil line installation verified. Fill with the appropriate oil.

A half pint or so can now be poured in the lower end. In the British bikes this can be done via the rocker covers by filling the rocker housings on both sides. Harley Davidson products have a timing plug on the left-hand crankcase, through which oil may be poured. A half to a full teaspoon of oil may be poured into each cylinder through the spark plug hole. Gently rotate the kick starter to help some of this oil film on the cylinder walls.

With the gas tank installed, and the timing set, we are ready to start the engine. The battery may require charging. Verify the correctness and tightness of all ignition connections which should be checked, along with an examination for frayed wires.

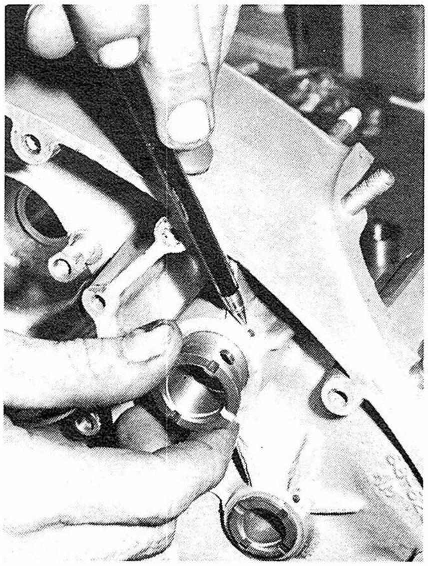
When the engine is fired, it is going to smoke until the pump catches up with the excess in the sump.

Immediately check the return in the oil tank. This should take place within 30 seconds, otherwise, check your oil line connections, and try again. Run gently at first.

During the first 200 miles, you should baby the machine, but don't lug it. At the 250- to 300-mile mark, an oil change should be performed. Also, and more important, the cylinder base nuts should be retightened. Doing this requires readjustment of the valves.

Repeat the oil change at 700 miles, and again at 1000 miles, at which time a tune-up is in order. Carburetion will have been reset at each oil change interval. Plug readings should be taken from scratch to final break-in. A good idea is to take a compression reading when the machine is first started and warm. This should be noted for reference, and checked every 1000 miles or so.

Having followed the outlined time consuming procedures, you will *not* have to cross your fingers hoping your engine will run. It will. And it will run well and this is the reward of building your own motor.



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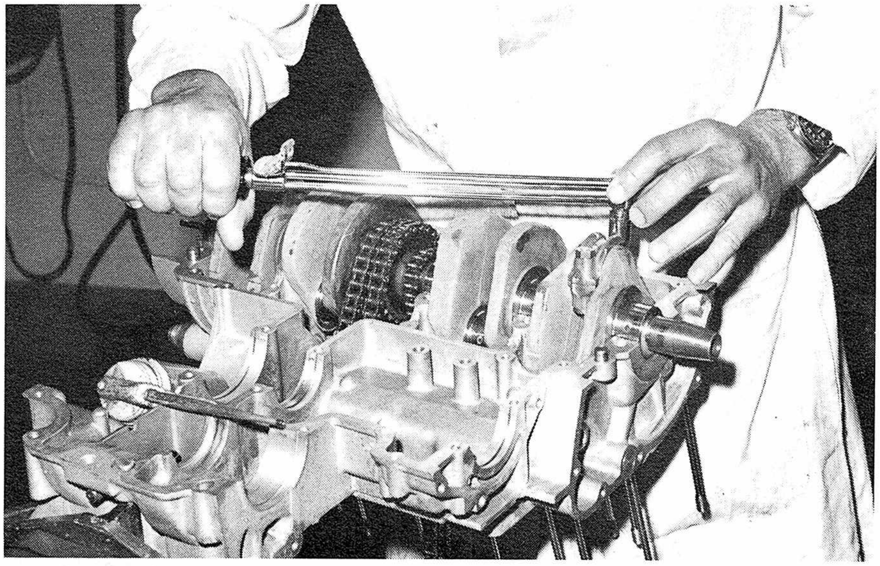

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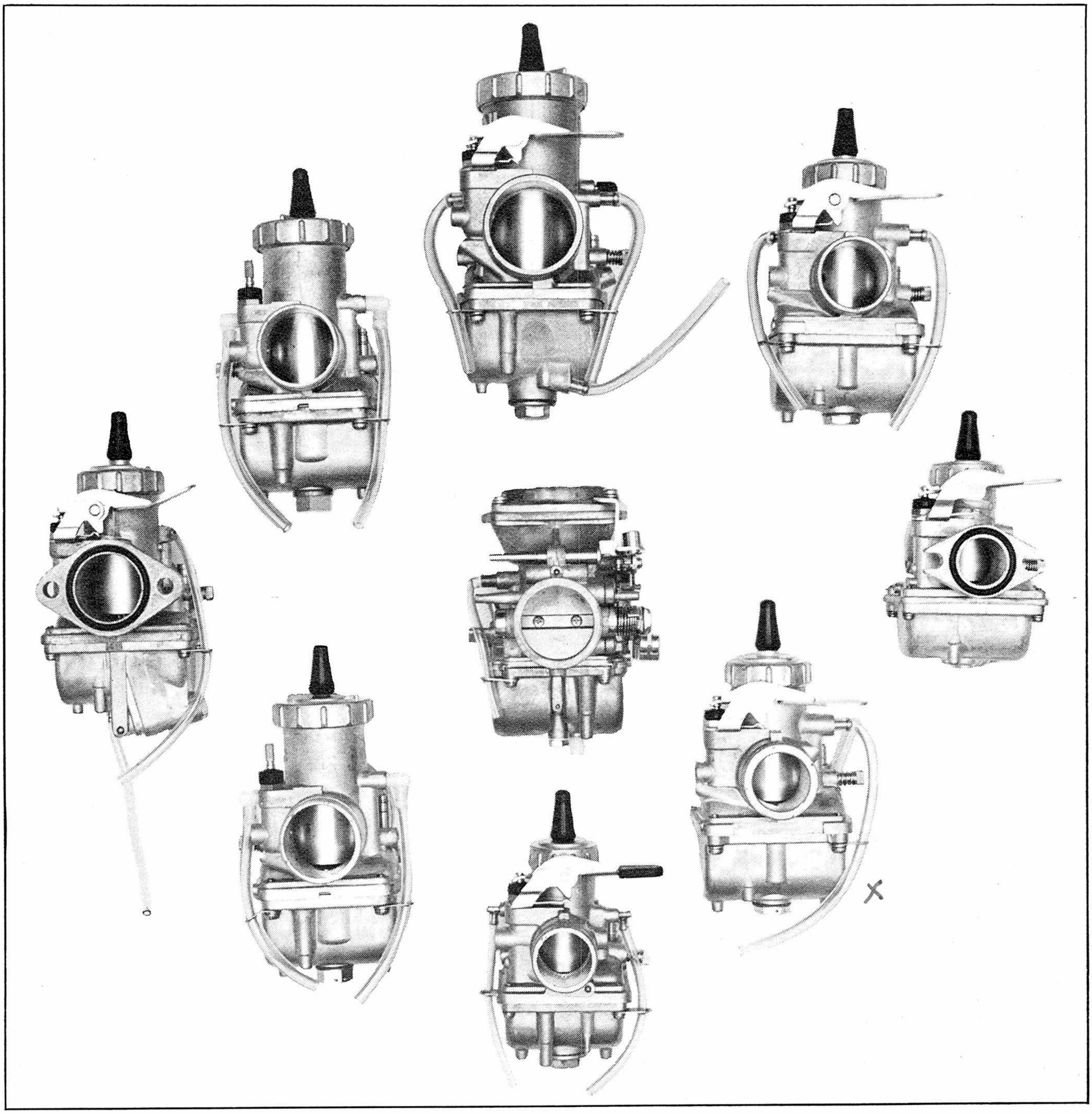
CARBURETORS AND FUEL SYSTEMS

Climb aboard for a fantastic voyage through the world of venturis, jets and atomizers

BY DAN COTTERMAN

Some years ago, I lived next door to a fellow who worked on wrist watches for space monkeys. In his off hours my friend invented things, and he was good at it. The only trouble was he didn't know when to stop. A masterfully conceived mechanism, revealed to my admiring eyes a few days earlier, would inevitably be embellished beyond recognition. The final unveiling would expose a spiny growth of bolt-ons and tediously machined mysterioso whose dimensions had managed to exceed every boundary of practicality. The spur for tampering with the well enough that should have been left alone probably grew from the inven-



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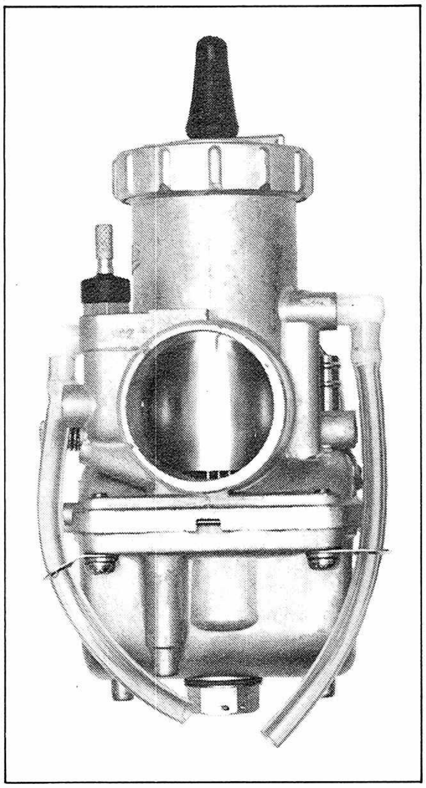

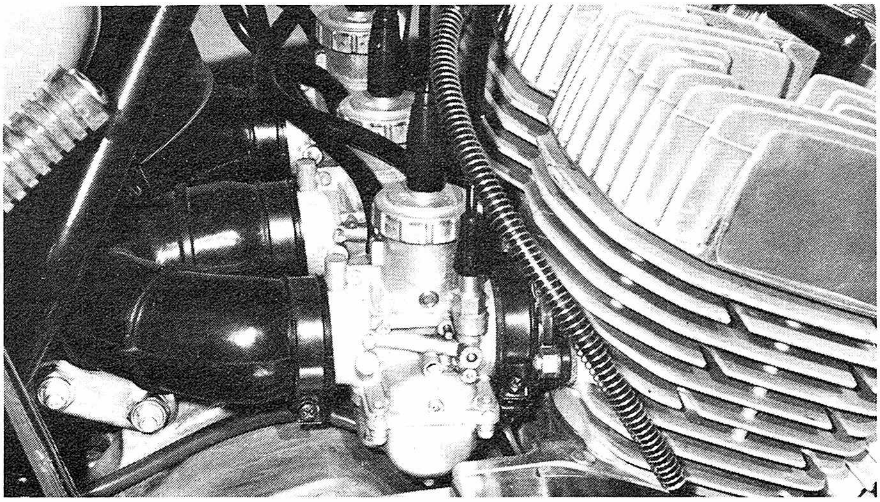

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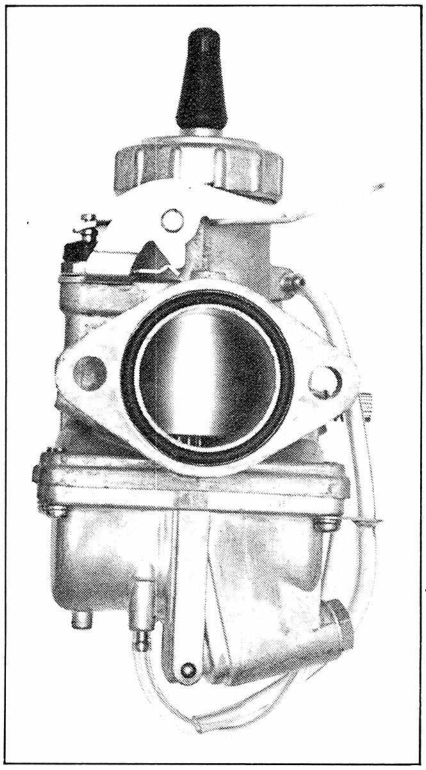

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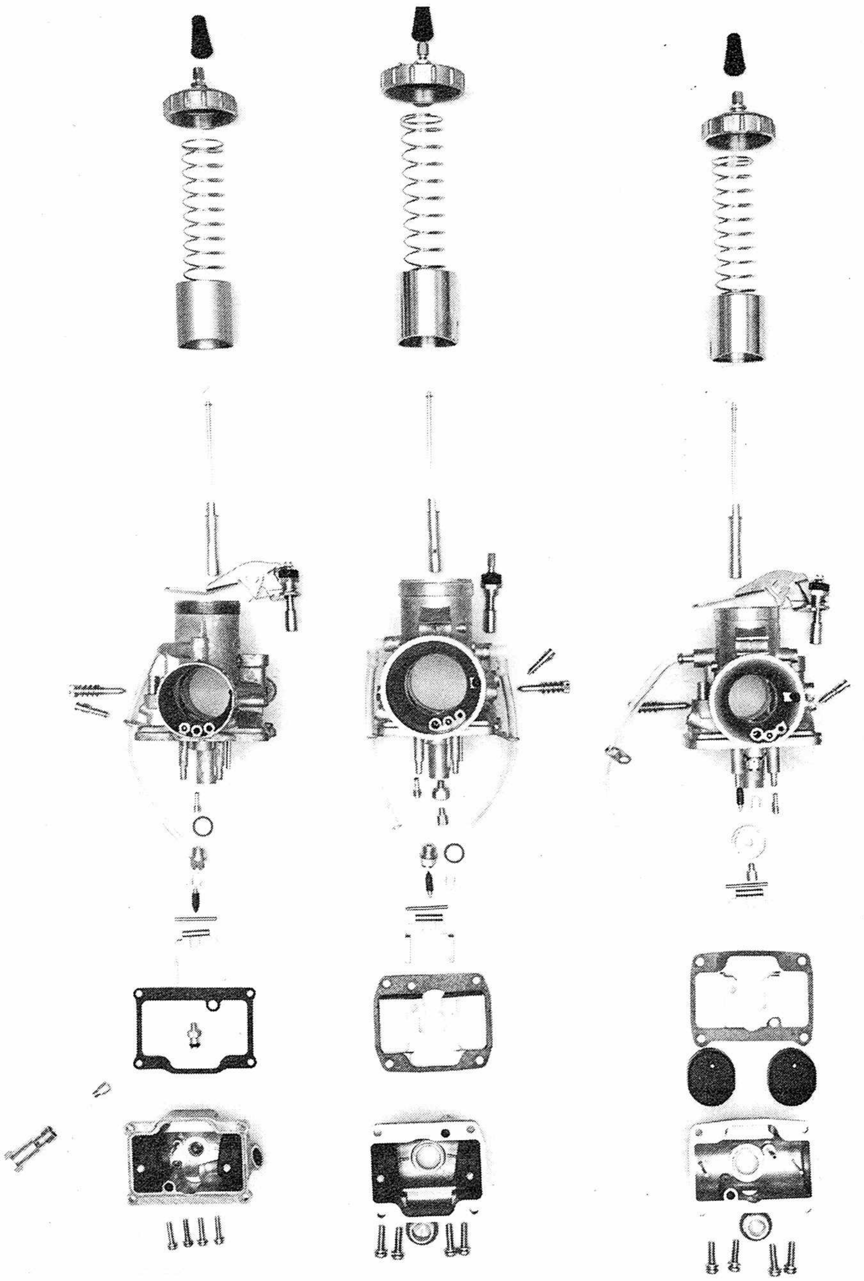

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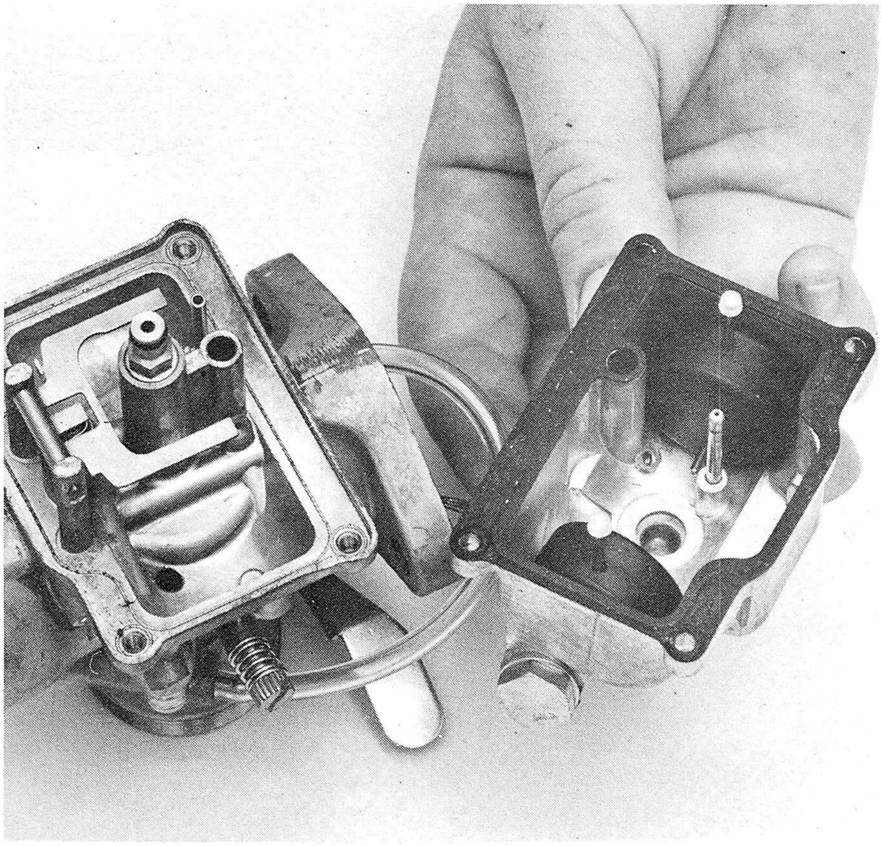
1. Mikuni spigot mount carburetor has become most popular mounting method. Access to main jet is through cap on the bottom of float bowl.

2. Flange mount model has main jet access in handy holder in side of float bowl. Both have different chokes and venting system.

3) Trio of "sliders" disassembled to show profusion of parts not present in "guillotine" carburetors which are discussed in text.

tor's passion for creating something that would fulfill numerous requirements.

Save for the fact that the carburetor as we know it today is the result of carefully controlled evolution, it might well be as big as a medicine ball and twice as heavy. In no other aspect of engine performance is so much demanded of so little. Without respect to its size this little device is called upon to instantly cater to the engine's constantly varying demands for different proportions of air and fuel. Necessity has demanded that it become a thing of sophisticated ingenuity. The fact that carburetor designs run from simple to complex should take nothing from our realization that their inbred sensitivity to an engine's running requirements makes them equally sensitive.



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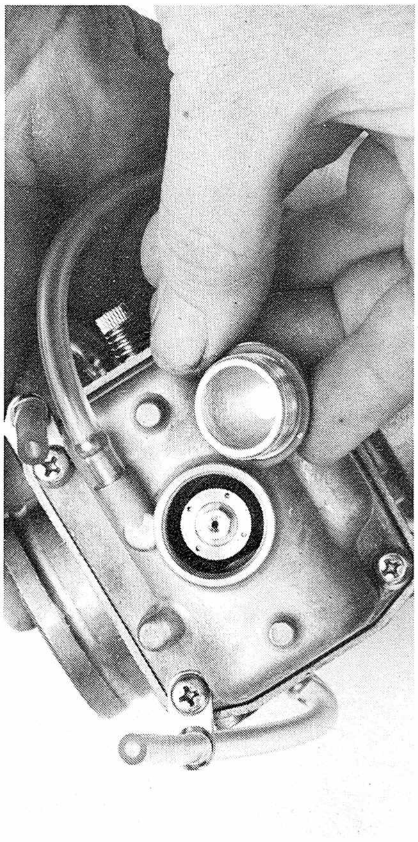

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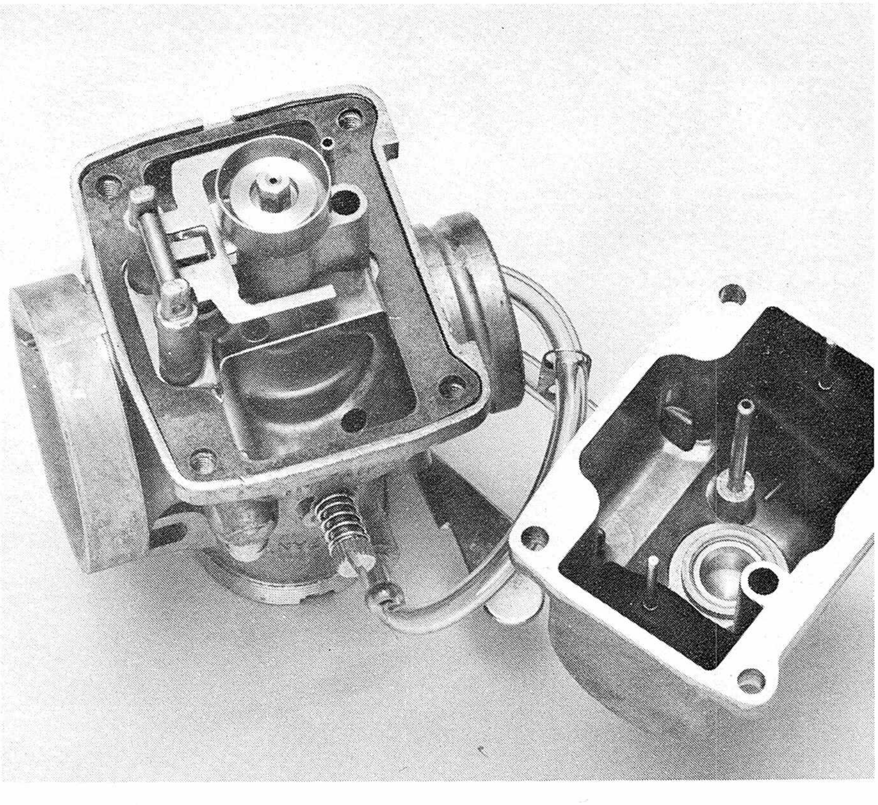

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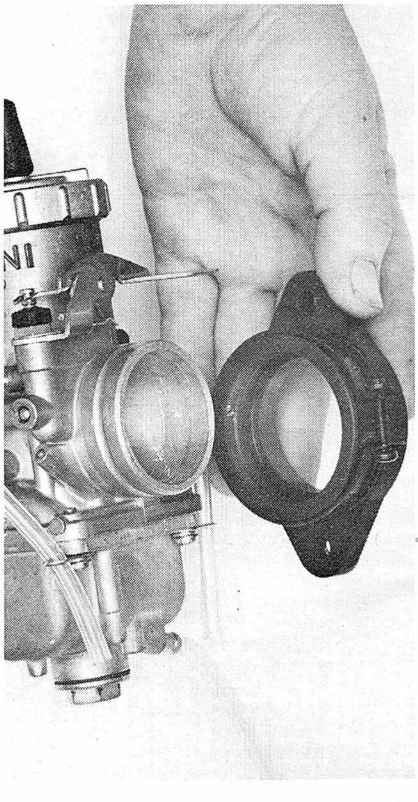

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Understanding the fundamentals of carburetor operation will be of tremendous value when we're faced with the challenge of analyzing problems. Quite basically, our concern is with a metering device. Fuel must automatically be measured into a venturi, an air passageway through the car-

1) Fuel bowl at right has dual floats which actuate forked valve lever. "O" ring is fitted to main jet (left center) to minimize leaks.

2) Here is bottom-up look at spigot type Mikuni with easy main jet access through underside of body—a good feature on competition machines.

3) Mikunis for bikes exposed to rough riding may have baffle surrounding main jet as guard against fuel slosh which results in engine starvation.

4) Here's the rubber flange spigot employed by Mikuni and others to insulate carburetor from damaging effects of engine heat and vibration.

5) Main jet needles must relate to size of jet orifice as well as height of carburetor. Each has adjustment "notches" cut around top end.

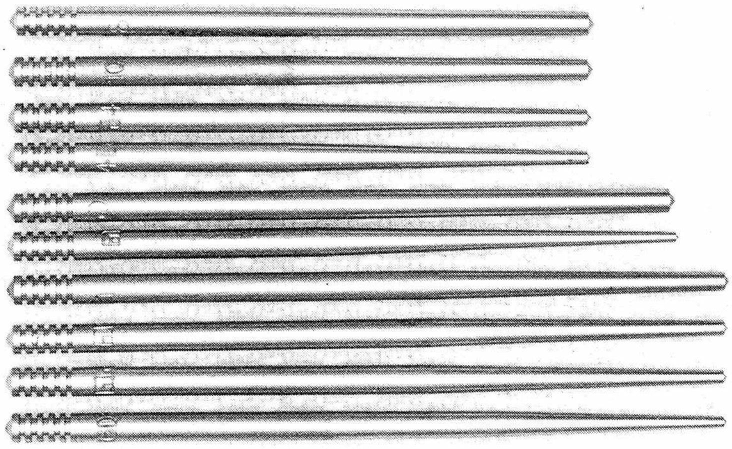
6) Intake side of carburetor shows slide fully closed, as with engine at normal free idle speed. Here is where idle and pilot jet adjustments affect running.

7) Throttle is now turned on slightly causing slide to rise. Engine is still being fed by pilot jet system at this point.

8) More throttle equals more engine speed as slide is drawn higher. Here slide cut-away is still a factor, but main jet needle setting begins coming into play.

9) This is how slide position might look at highway cruising speeds. Job of metering fuel is dependent upon both needle setting and main jet size.

10) Full-throttle position raises slide up and out of picture. Now main jet size is a real factor in performance.



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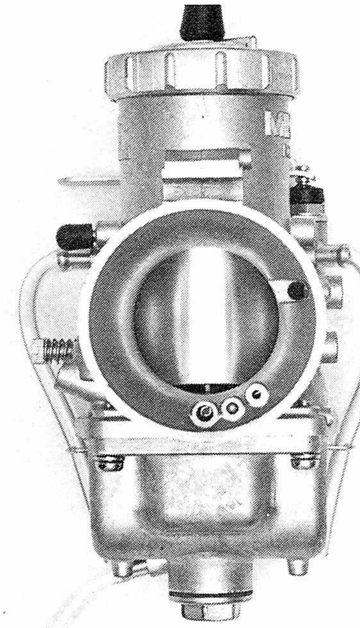

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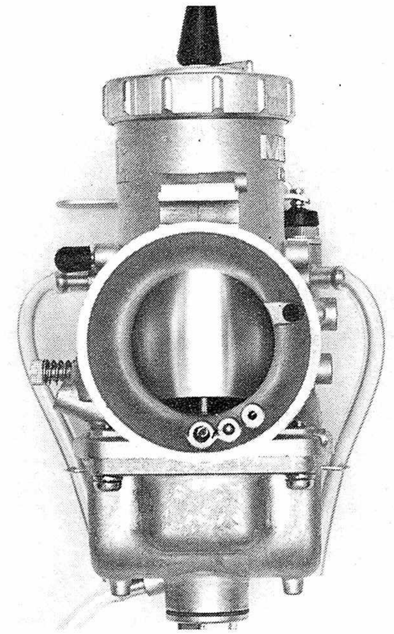

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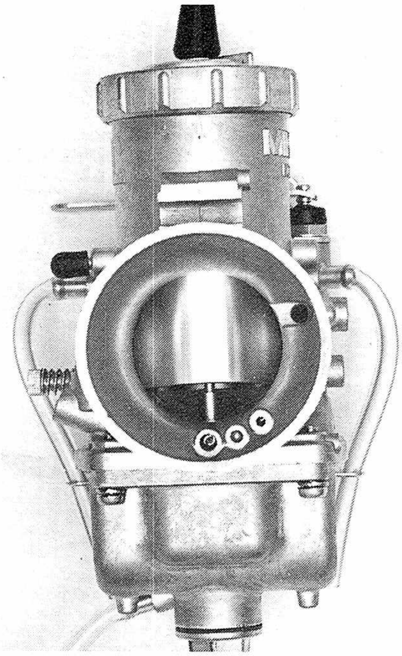

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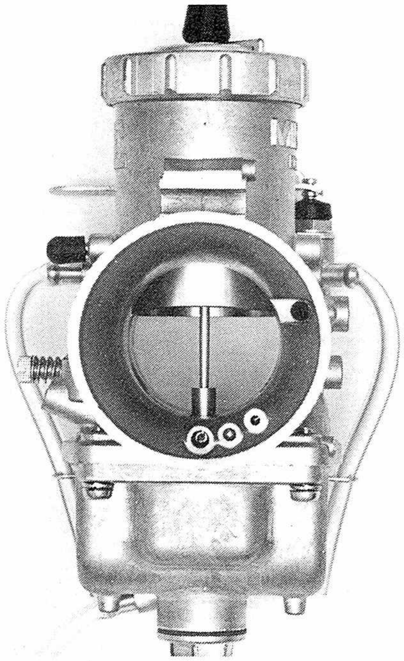

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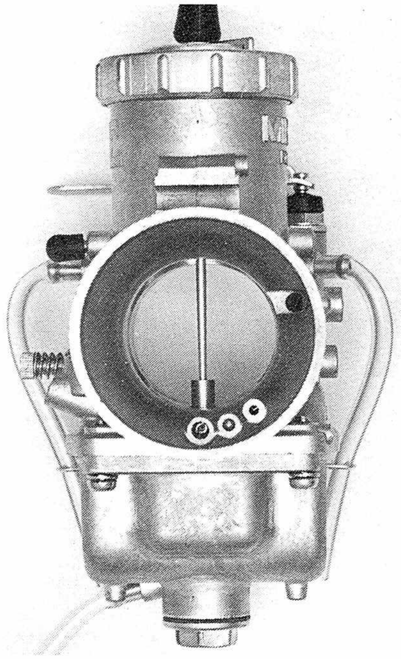

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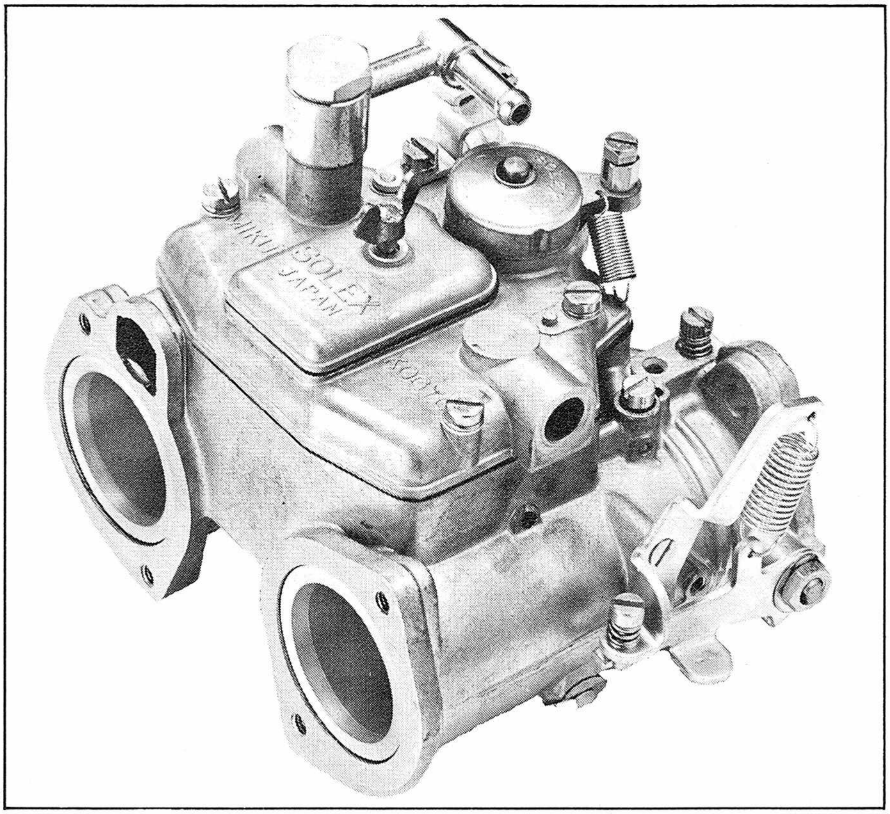
buretor body, where it can become atomized and drawn into the engine cylinder for combustion. The foregoing would seem to profoundly oversimplify the supply of a combustible vapor to an engine. However, we will soon note that some of the best motorcycle carburetors available today are, indeed, profoundly simple!

I mentioned the engine's constantly varying demands for different proportions of air and fuel. A few seasons back Shell's "Answer Man" told us that the optimum air-fuel mix for an engine, just cruising easy, was about fifteen parts of air to one part fuel. He was, of course, directing his statement primarily to automobile owners, but the same ratio applies to motorcycle engines. Let's go a little further. Using that 15:1 ratio as a basis for comparison, we find that a mixture approximately twice as rich is needed during engine starts and, furthermore, that each of the several conditions of engine loading and speed will de-



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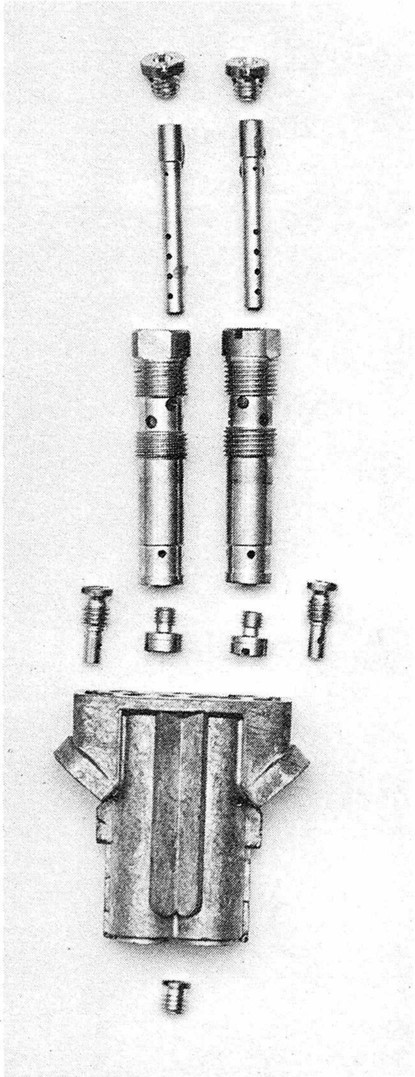

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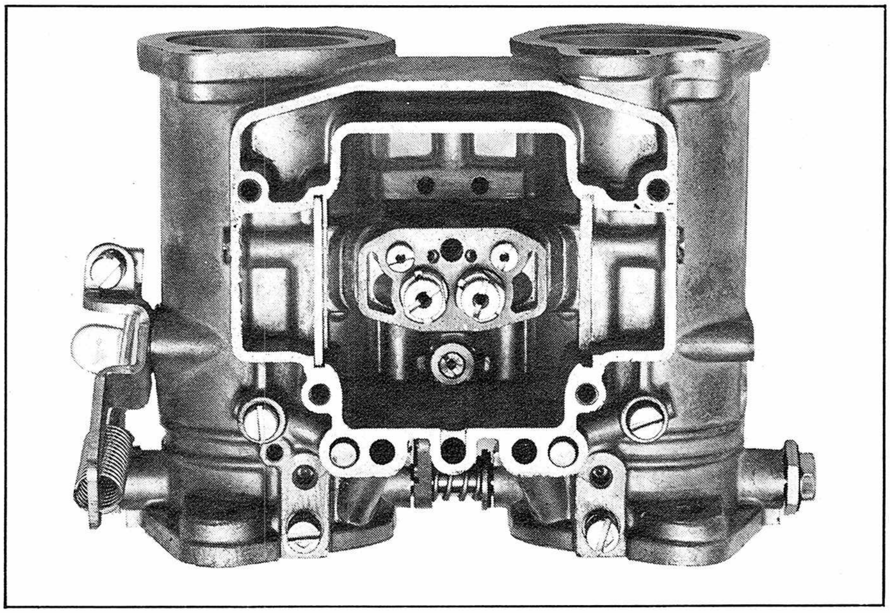

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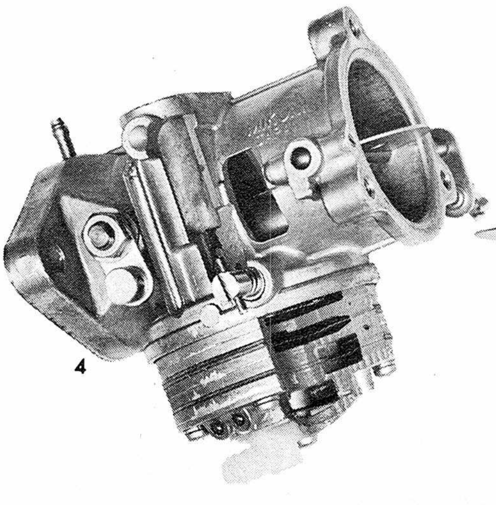

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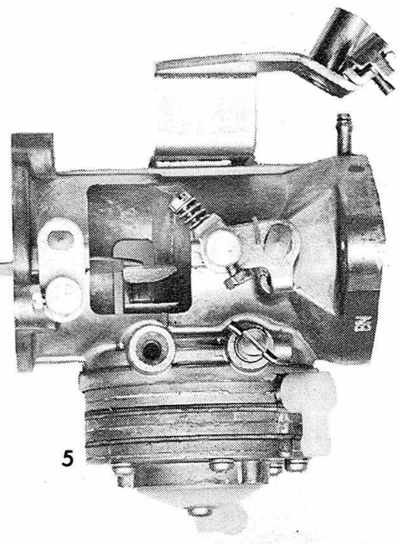

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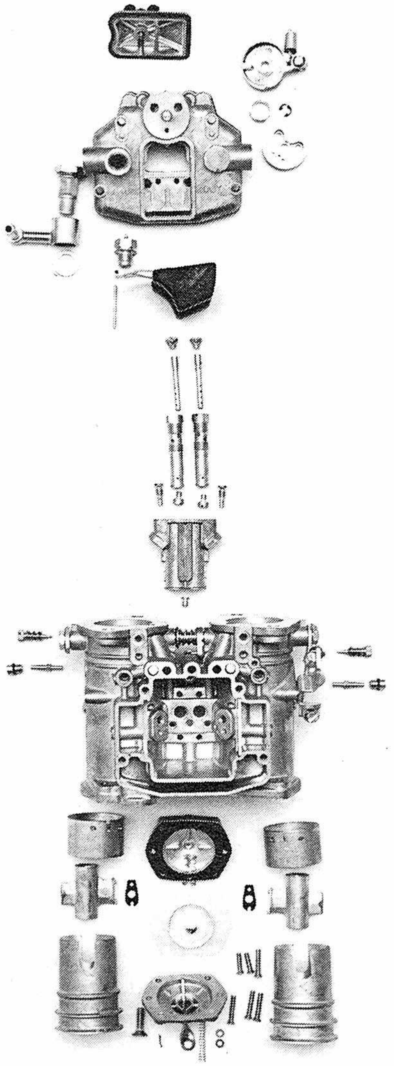

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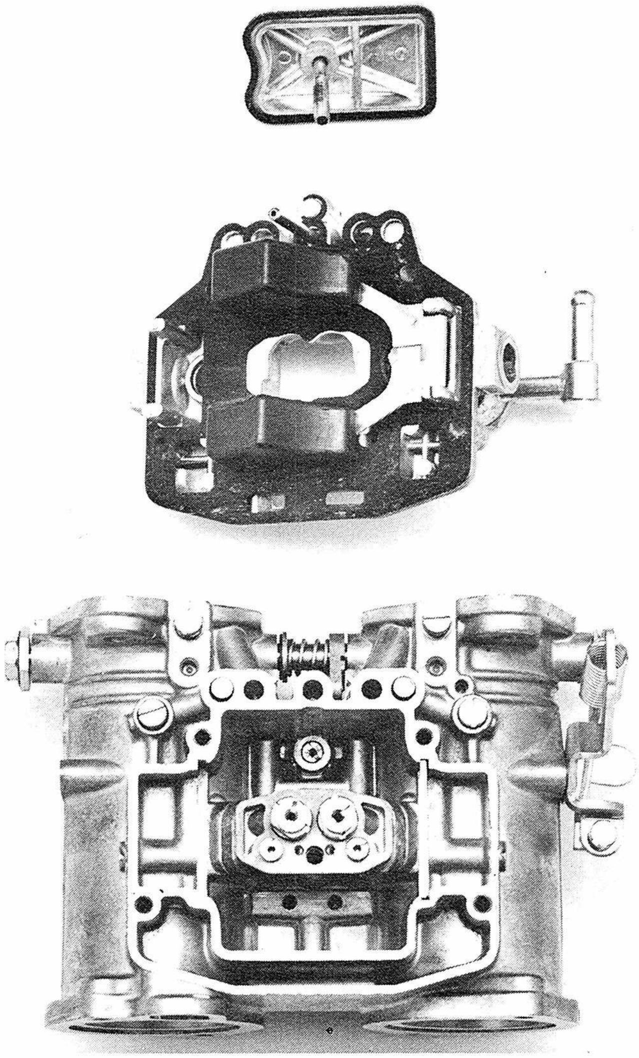

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1) Comprising Mikuni Solex "jet set" are these matched nozzles, jets and brass inspection cap screws. Jet block is seen at bottom of photo.

2) Here's the "racer's edge" for your Mini Enduro, the twin throated Solex shown here intact. Note throttle linkage, wingnut access on top.

3) Looking down the well as Solex is viewed from topside. Jets and nozzles at center can be removed by means of slotted heads. Idle set is on left.

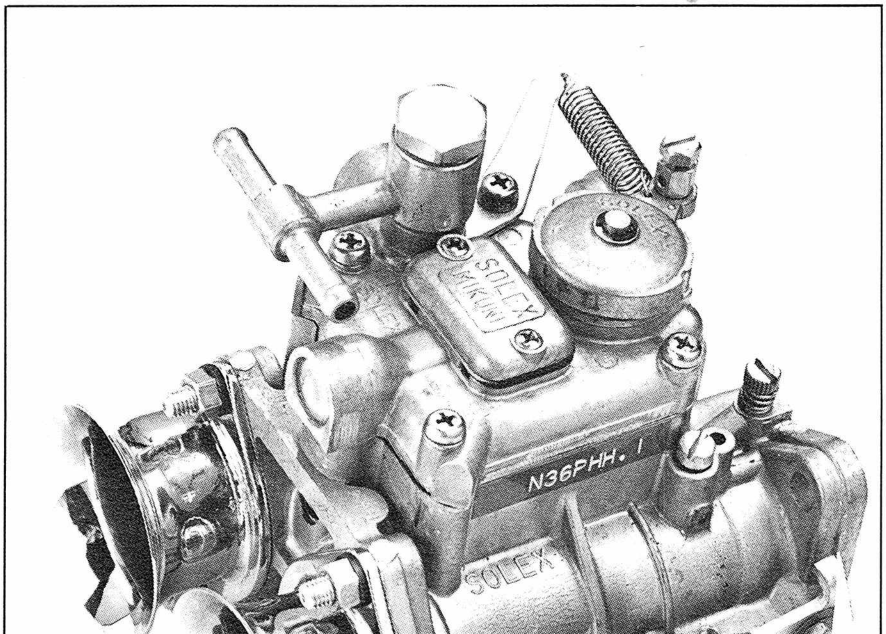
4) Thatch of Mikunis includes this butterfly-diaphram pumper, cut away here to show venturi, butterfly valve and multiple diaphrams in bottom.

5) Same snowmobile pumper as in previous photo, this time showing linkage, outside adjusters and throttle valve fully open to actuate plunger.

6) From the top: inspection cap, float assembly and main carburetor assembly. Note presence of intervening gaskets, outside adjustment screws.

7) If you thought the Mikuni slide carburetor had a lot of parts, dazzle your orbs over this Mikuni Solex of the Weber side-draft type for cars.

8) Variation of Solex has different throttle linkage and topside assembly. Jazzy chrome stacks help add that fast appearance. O' Solex mio!



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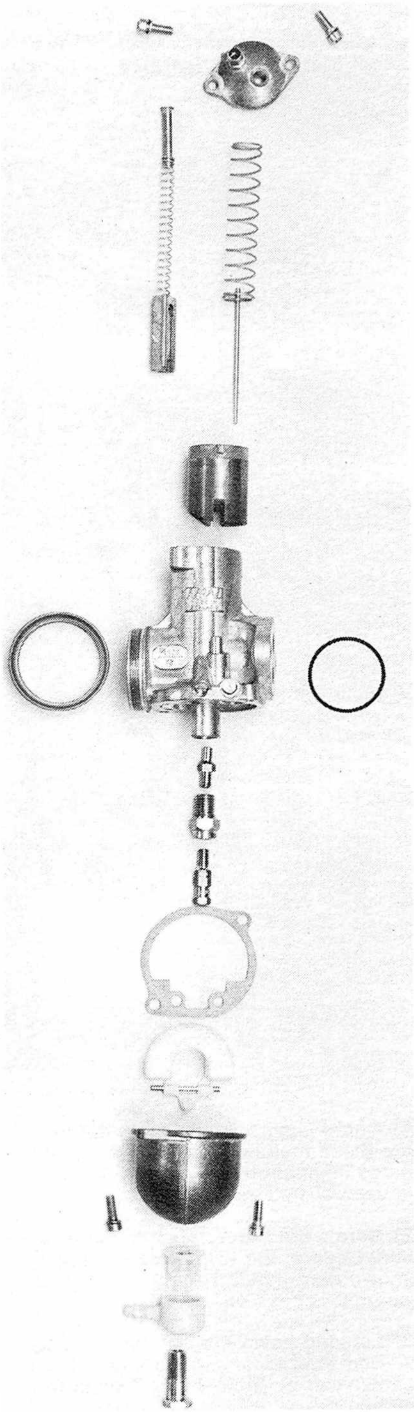
mand still other degrees of richness. Complicating matters even more is the variance of air-fuel combination requirements imposed by substantial changes in altitude.

THE SLIDERS

Although not the simplest, the piston-valve or "slide" types are among the oldest and most dependable. Certain individualities notwithstanding, this type would include the bulk of carburetors now being manufactured by Amal, Bing, Dellorto, IRZ, Keihin, Mikuni and a couple of others I may have neglected to mention. Each of these involves the supply of a progressively greater air/fuel mixture through the facility of a slide and a tapered needle that go up together as the throttle is "dialed on." As nearly infinite and controllable as it may be, the tapered needle being gradually withdrawn from the orifice of a main jet does not satisfy the requirements of the engine at idle and low engine speeds. For this purpose a pilot jet system has been incorporated.

To follow each stage of slide carburetor action we must first picture the engine at idle. In this condition the throttle is closed and the slide is held only slightly open by means of the physical stop provided by adjustment of the throttle stop screw which projects upward at an angle through the side of the carburetor body. At this point, the tiny pilot jet is doing the metering. As the throttle is turned to raise engine speed moderately above idle the volume of air is no longer dependent upon the adjustment of the throttle stop screw because the slide has been lifted to a point where the "cut-away" on one side of the skirt provides a larger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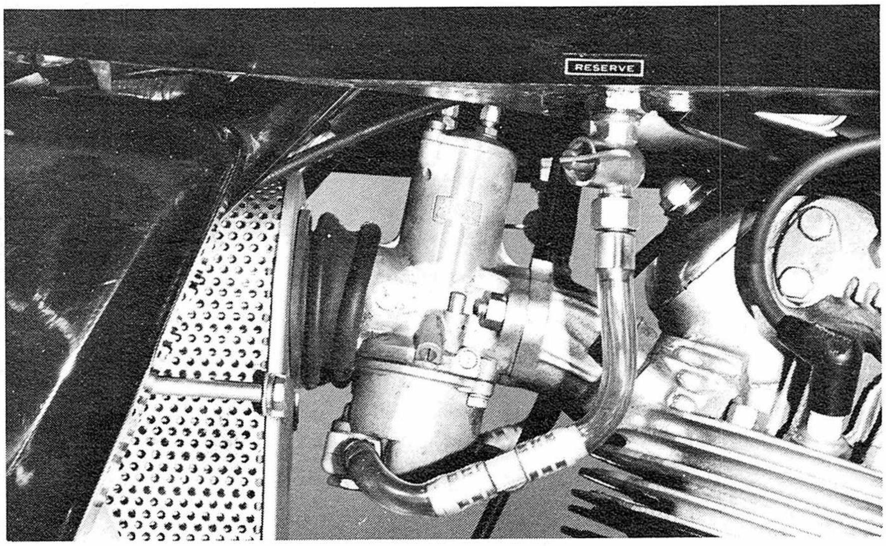
AMAL



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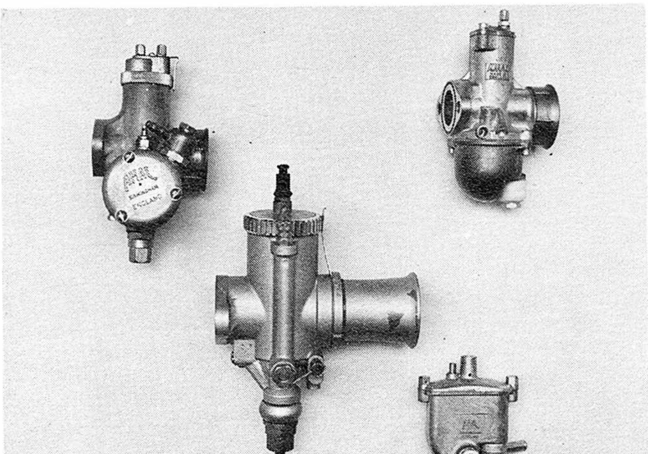
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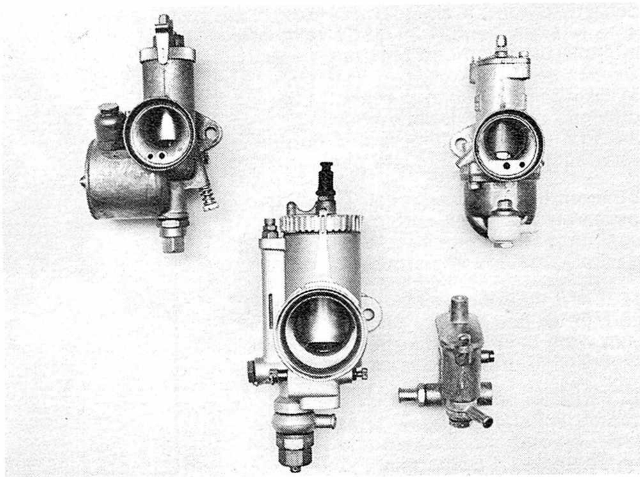
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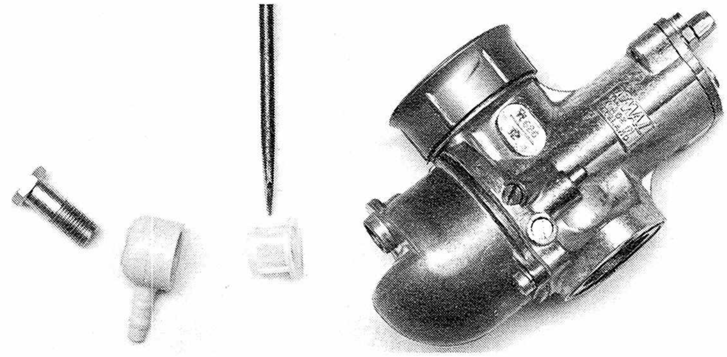

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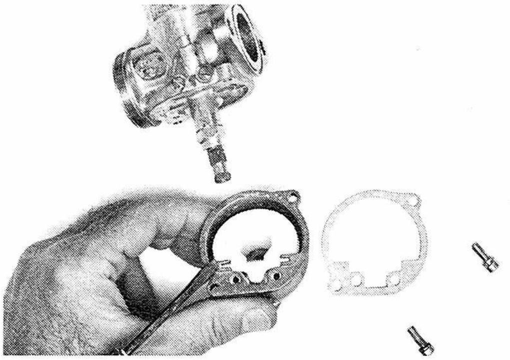

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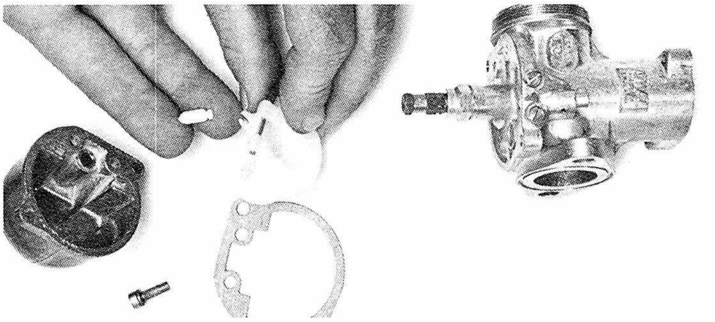

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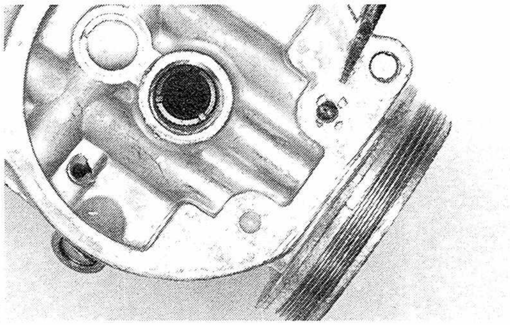

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1) Amal carburetors have found world wide acceptance on European machinery. They have seen few changes over the years. These shown are British Amals.

2) "Exploded" concentric reveals about 15% fewer parts than Mikuni version. Complete gasket sets and overhaul kits are available separately.

3) British Amal slide-type carburetors are, L-R: Mono-Bloc, Grand Prix (with satellite fuel bowl) and latest improvement known now as Concentric.

4) Another view of Amal threesome. Note differences in float bowl locations. Concentric, far right, is best. Late bowls now have main jet access.

5) Pictured beneath Amal Concentric are metal "banjo" bolt with single banjo and fuel filter gauze. Latter must be inspected and cleaned often.

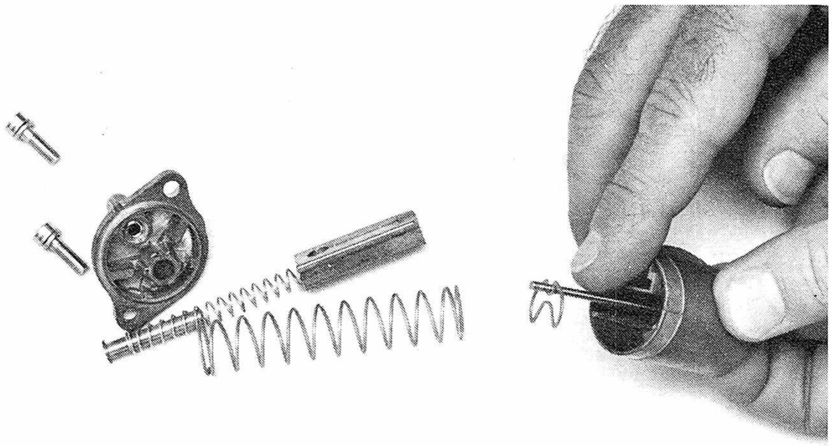
6) Concentric float bowl removed to show tiny "toilet-seat" float and pivot. Re-install very carefully.

7) Here's why: Small forked tab on pivot end of float must engage slot on end of float needle. If not, a spate of fuel will flood carburetor.

8) "Stab" crimp holds part of pilot idle system in Amal body. Concentric body casting is made to be drilled and tapped for use on left or right.

9) Pointing to small copper clip used to position main jet needle in slide. Clip in top notch = lean operation, bottom notch = rich running.

10) Concentric jet block is removed, top, as screwdriver is poised to adjust idling mix at pilot air screw. Larger knurled screw is slide stop.



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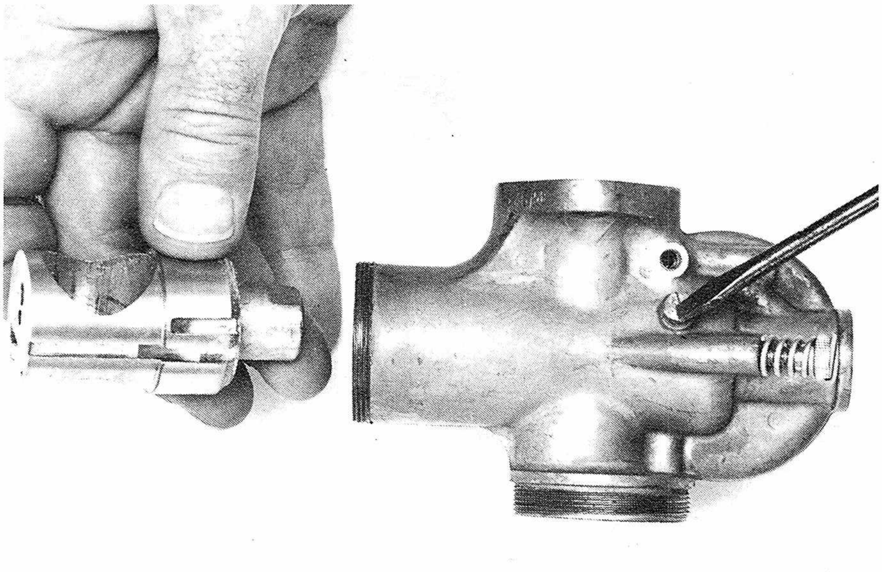

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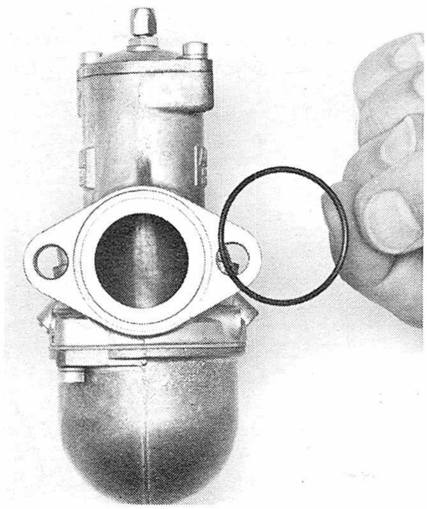
CARBURETORS

opening to the venturi. This intermediate stage finds the supply of fuel from the pilot jet augmented by the initial traces of spray from the main jet as that tapered needle I mentioned a minute ago is lifted with the slide to begin its withdrawal from the hole in the main jet. Now we can follow the progressive rise of the slide as the throttle is turned on a little further and see that the general state of carburetor "tune" will be primarily influenced by the position of our tapered needle and its relationship to the hole in the main jet. Please note that it isn't until about three-quarter throttle is reached that the size of the main jet becomes a factor in tuning. There is a tendency among many riders to start changing main jets when their problem exists in some other stage of carburetor operation.

You might find more difference than agreement among the several makes of slide-type carburetors. The operation principle is about the same for all. The differences start stacking up when you look at details of construction. Dellorto, for example, uses a square slide in their center-bowl models, now widely used on Ducati and Moto Guzzi machines. The advantages, according to A.J. Lewis who now heads the service depart-



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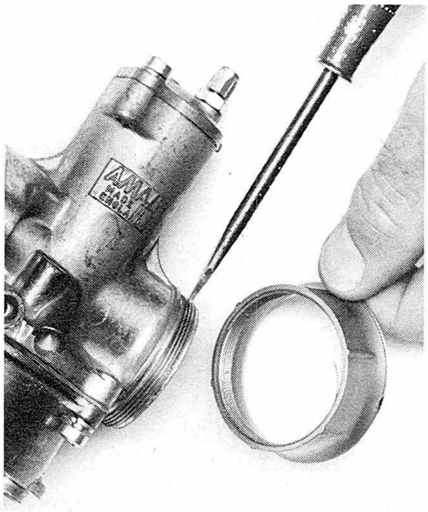

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1) This is the flanged end of the Concentric that bolts to intake manifold. "O" ring fits into machined groove, provides airtight operation.

2) All together now, a final look at Concentric cautions us to be careful when turning velocity stack or air filter onto these fine threads.

3) Venerable Amal Mono-Bloc disassembles easily, reveals about as many parts as Mikuni slider. Float bowl is at side, can cause mixture changes.

4) Mono-Bloc "O" ring seal is shown at left, while screwdriver points to filter gauze used to clean fuel as it enter float bowl from topside.

5) Side-mount float bowl of Mono-Bloc is seen here with float, float needle and small pivot bush removed. Metal float needle also available.

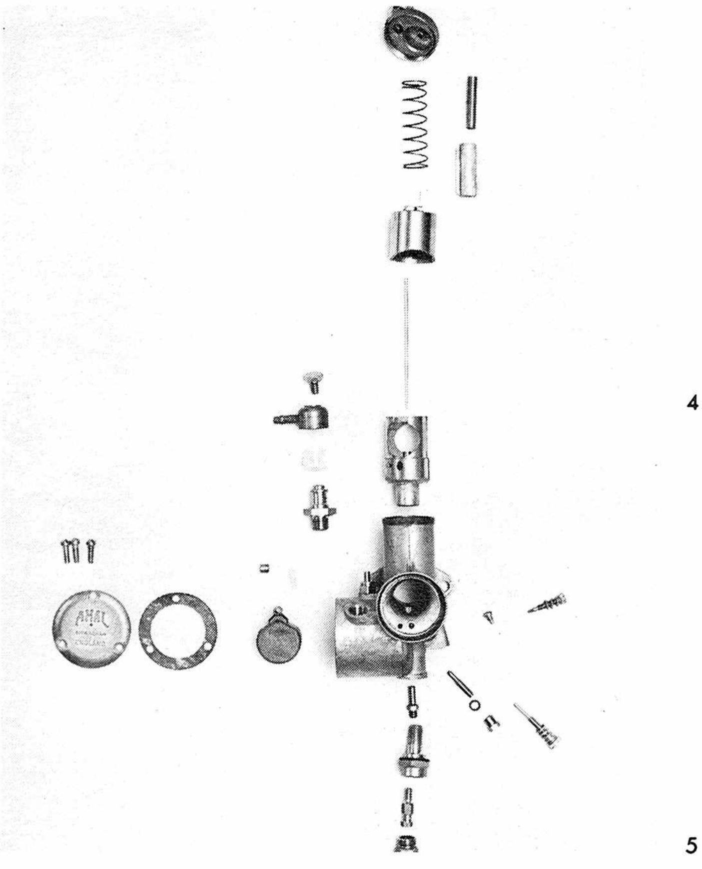
6) Mammoth Amal Grand Prix is expensive version with remote float bowl to provide large volume of air-fuel mixture for racing. Count the parts!

7) Grand Prix models, intended primarily for competition, are designed for quick, easy access to main jet. Jets come in larger sizes for alky.

8) For more sophisticated and quicker tuning in pits, Grand Prix has externally adjustable float level. The float is a small brass vesicle.

9) A big slide for the Grand Prix holds adjustable needle at side with small spring clip to hold setting. Note largeness at needle's lower tip.

10) Grand Prix velocity stack screws off. Tab on flat strap engages notch in ring, secures stack while other end helps hold top cap on carb body.



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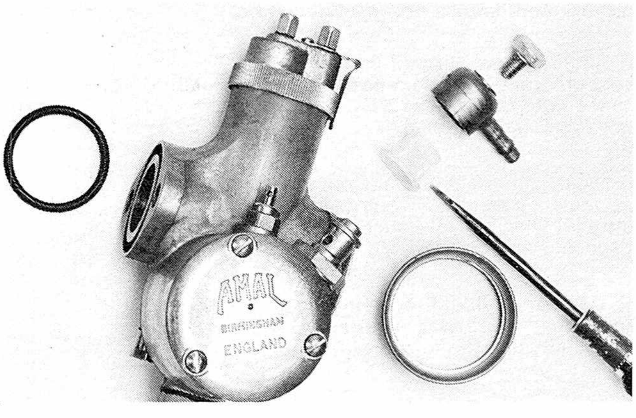

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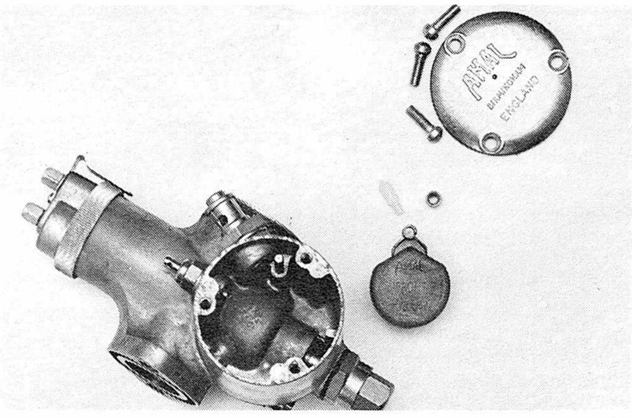

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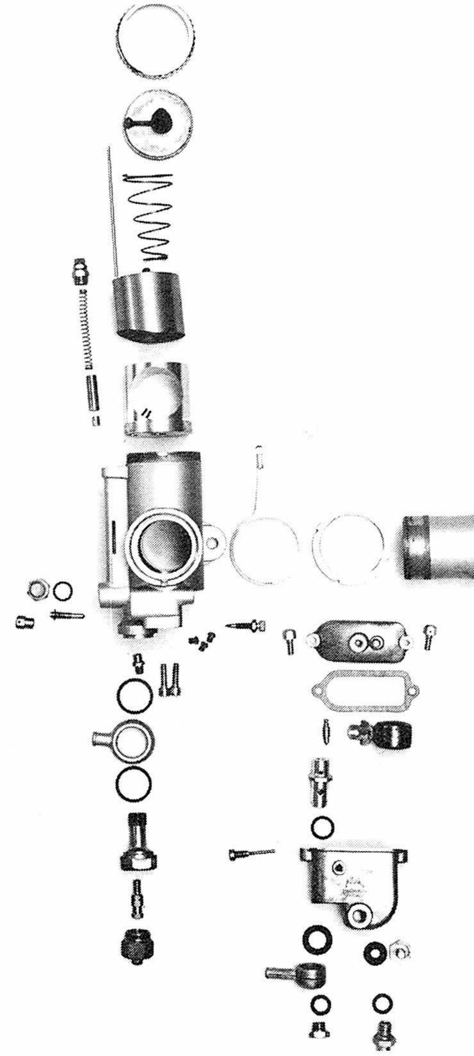

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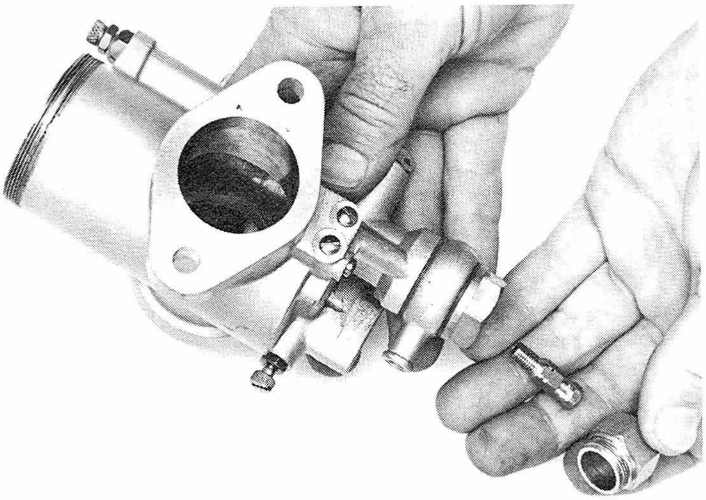

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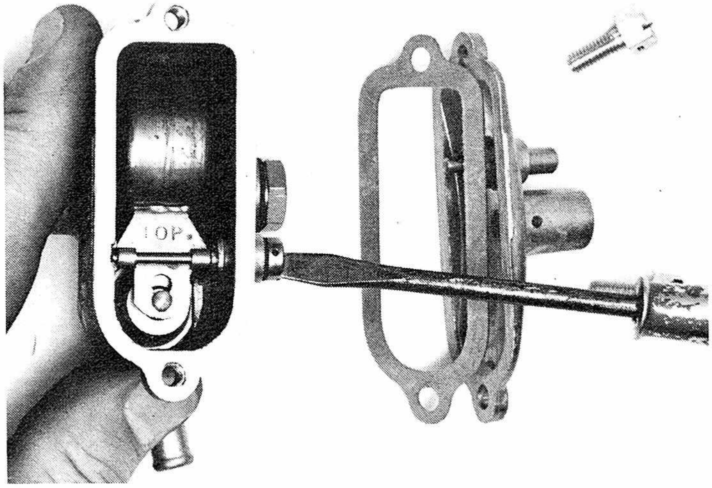

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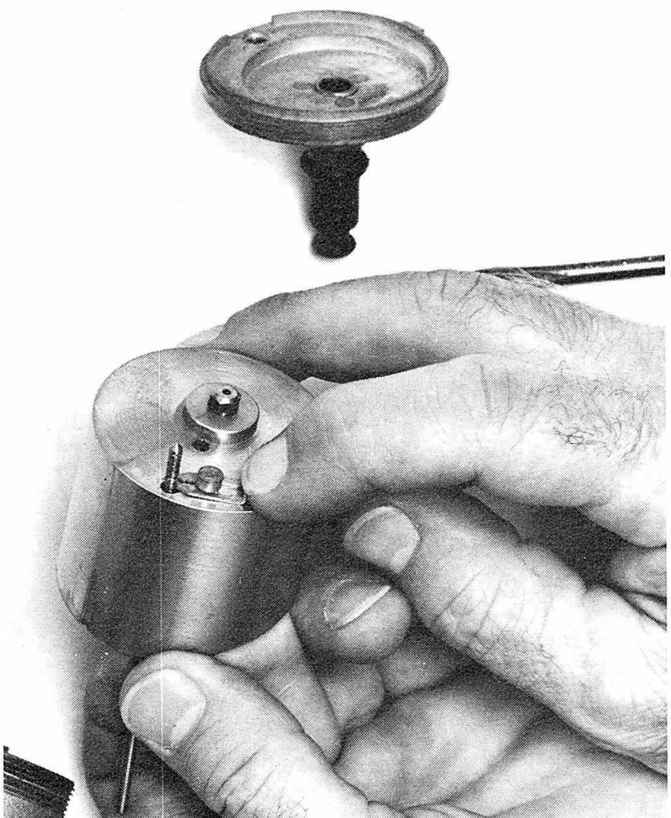

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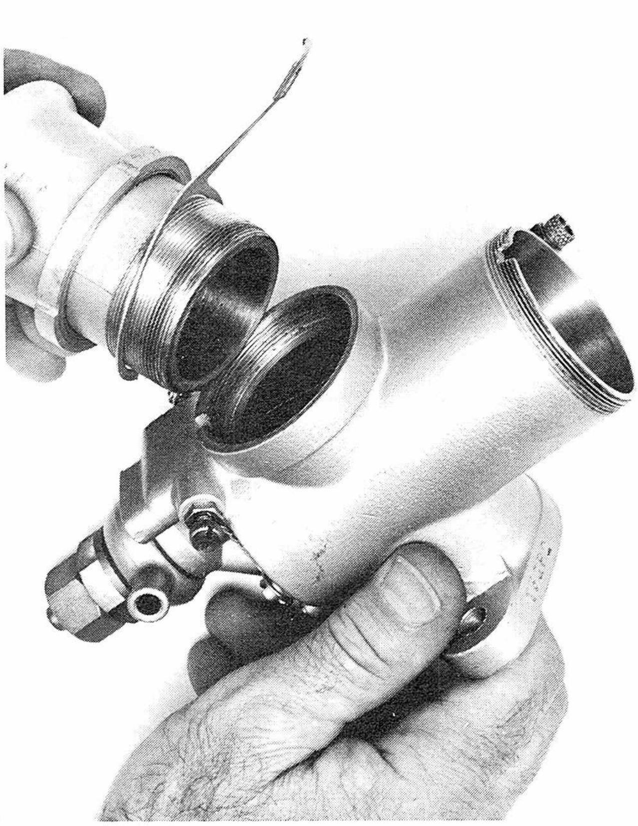

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ment at the "Duke" and Guzzi western headquarters, include easier slide action—which has to mean less sticking—and vastly increased slide life.

New Hondas with slide-equipped Keihin carburetors have attempted to create a situation of more positive up-and-down slide movement by innovating a dual-cable system. The idea is that one cable pulls the slide up and the other pulls it down, depending on which way the throttle twist grip is rotated. This may be the breakthrough that will finally take slide action out of the yo-yo category by giving the rider positive two-way control. It also may eliminate the need for using solid brass slides, simply because they're heavier and, for that lone virtue, seem to return better. Of course, an aluminum slide in an aluminum carburetor body is supposed to be bad, but mere brass plating usually is sufficient.

There was a lot of talk about slide replacement, perhaps as often as each year on dirt bikes. Bob Nicholson of Ossa stresses this necessity by pointing to the fact that a piece of the skirt of a badly worn slide can sometimes be drawn into an engine with resulting top end damage.

An interesting and original feature of the IRZ slide-type carburetor is its incorporation of duality. Dual fuel line feed to the float bowl, dual air adjustments to the low range stage and dual needles for smoother stage-to-stage acceleration. The two needles, slightly different in length, are intended to offer phase graduation without performance flat spots sometimes encountered with less developed systems. The problems with adjustment of a carburetor of this type are not with the design, but with the tinkerer who doesn't know adjustment procedure. At this juncture we might well

1) Dual needles, jets, adjustments, etc. of IRZ carburetor pose challenge to both Mikuni and Amal Grand Prix for array of parts. However, system is okay.

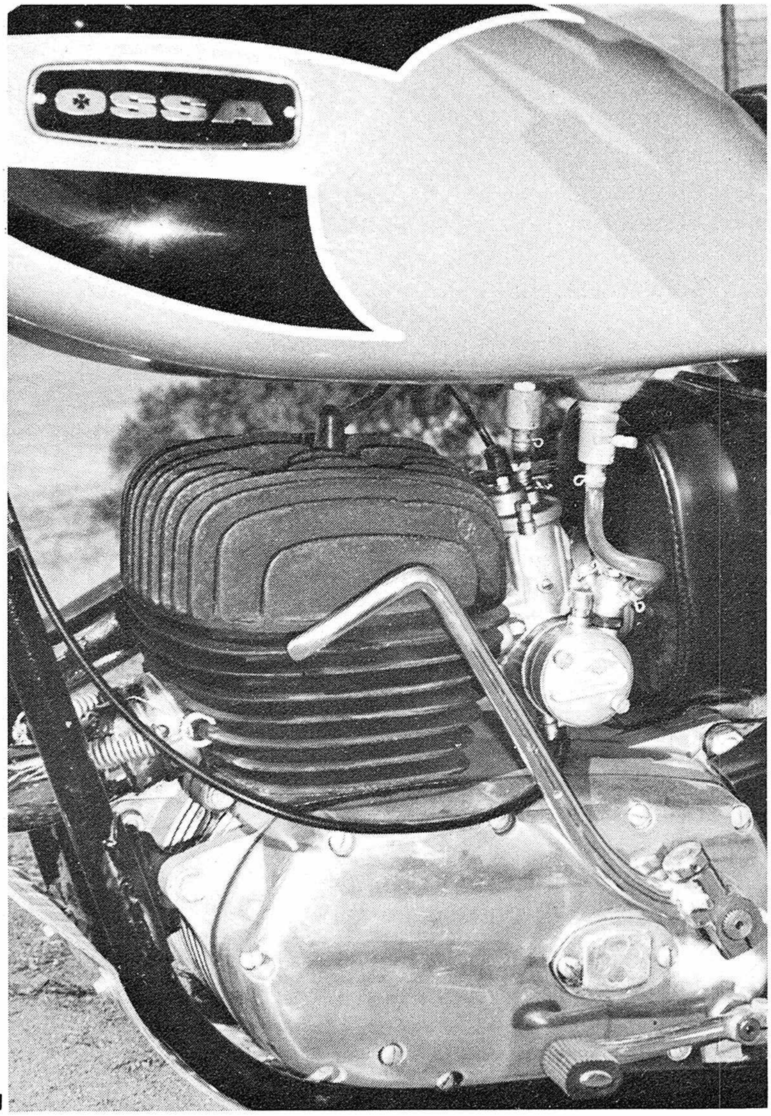
2) Not a leaky float bowl, cutaway is made to show IRZ's metallic float, float needle and tickle-button assembly. Also fuel intake and filter.

3) Reverse side cut away shows IRZ's slide, pilot air intake system (T-shaped channel), plus dual needle and jet set-up in lower chamber.

4) Say, "IRZ!" Looking down throat of carburetor offers clue to double needle function. Adjustments easy to get to. Note bolt-on bottom cover.

5) Assembled and ready to go, IRZ is smooth, trouble-free unit if you take time to learn how to adjust it. Follow manual, one stage at a time.

IRZ



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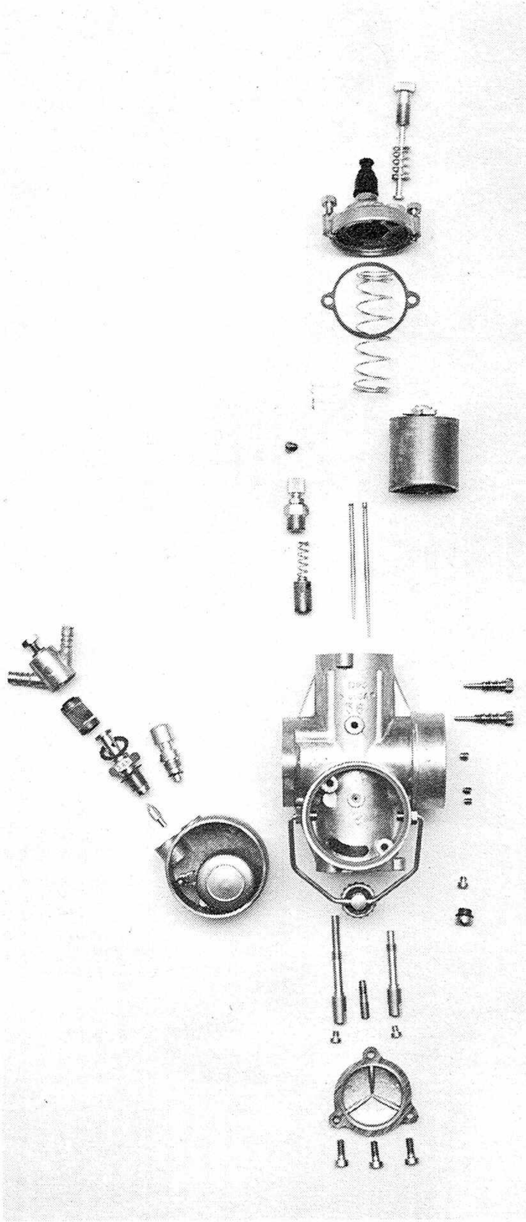

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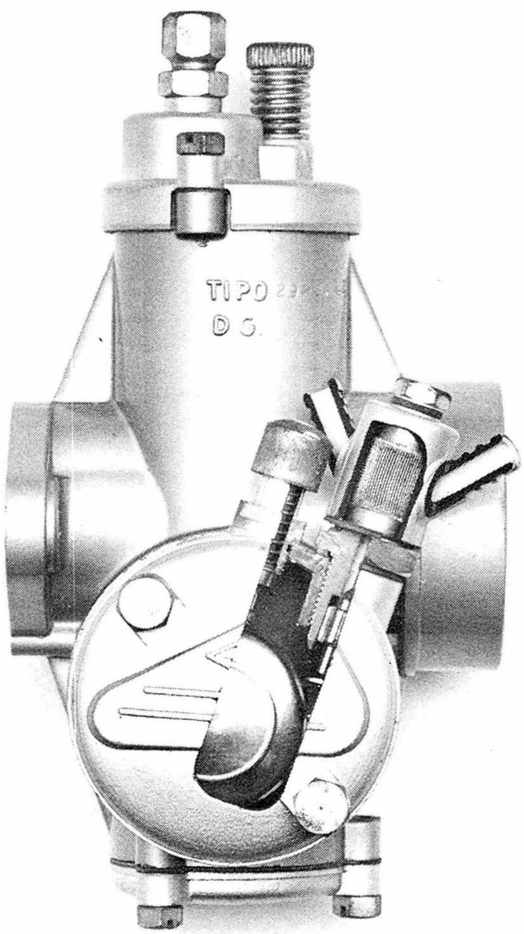

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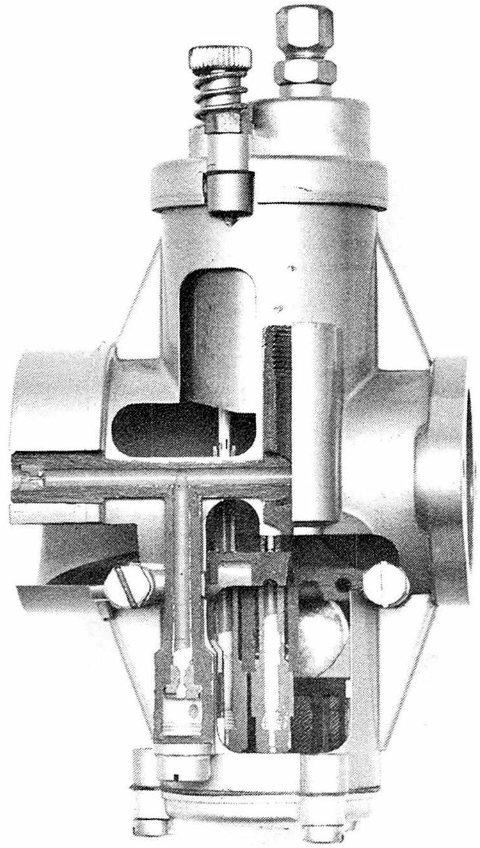

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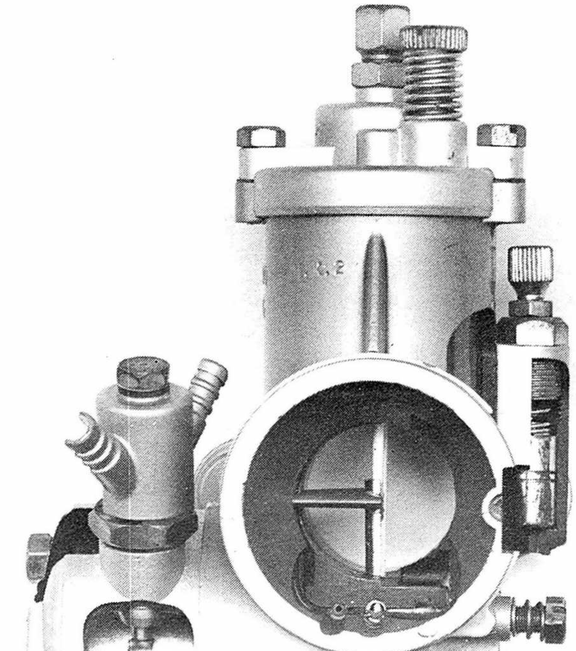

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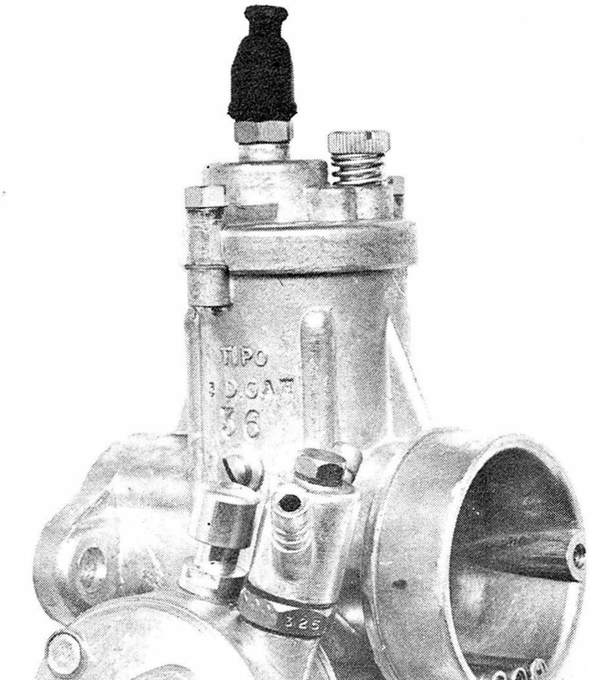

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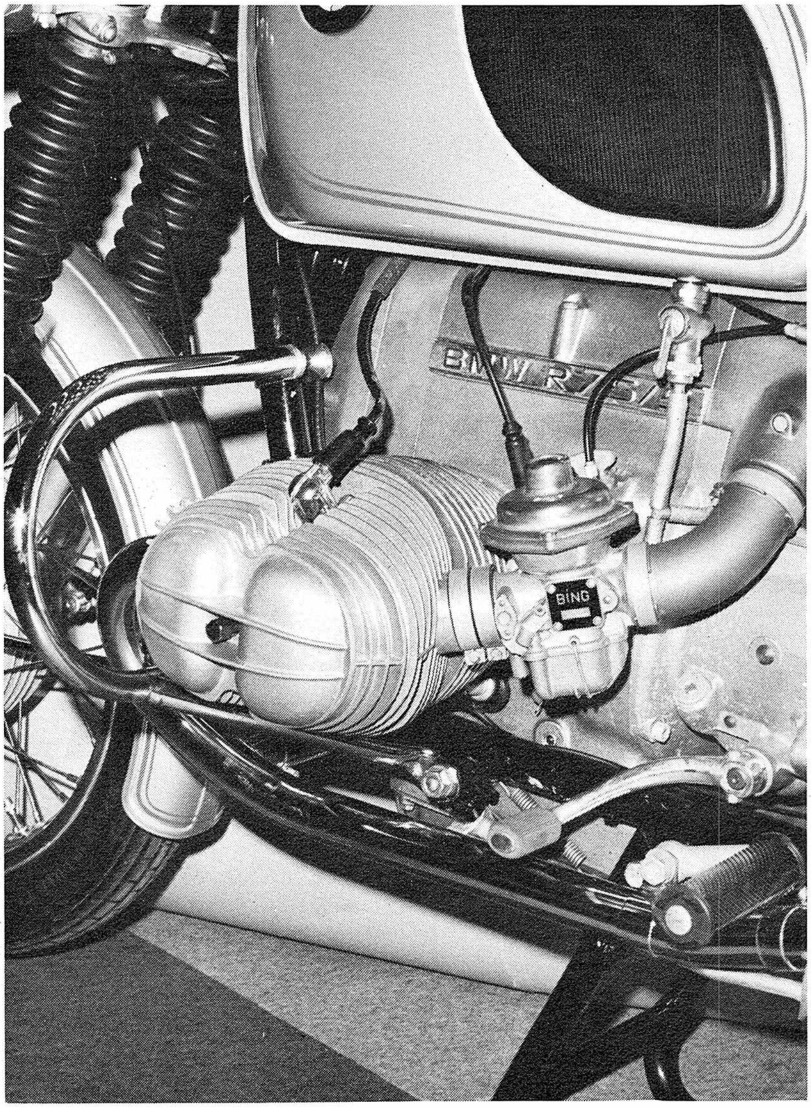
remember that stage-by-stage adjustment is invariably recommended with any carburetor, starting with low speed and working up. If, as we have noted, the amateur tuner begins by changing the main jet when his difficulty actually exists elsewhere, he should heed the warning of Bultaco's Tom Patton who observed that a change of main jet might act to alter flow characteristics in other jets throughout the carburetor. Don't let the need for a minor adjustment in one of the low-range stages trick you into getting everything out of shape.

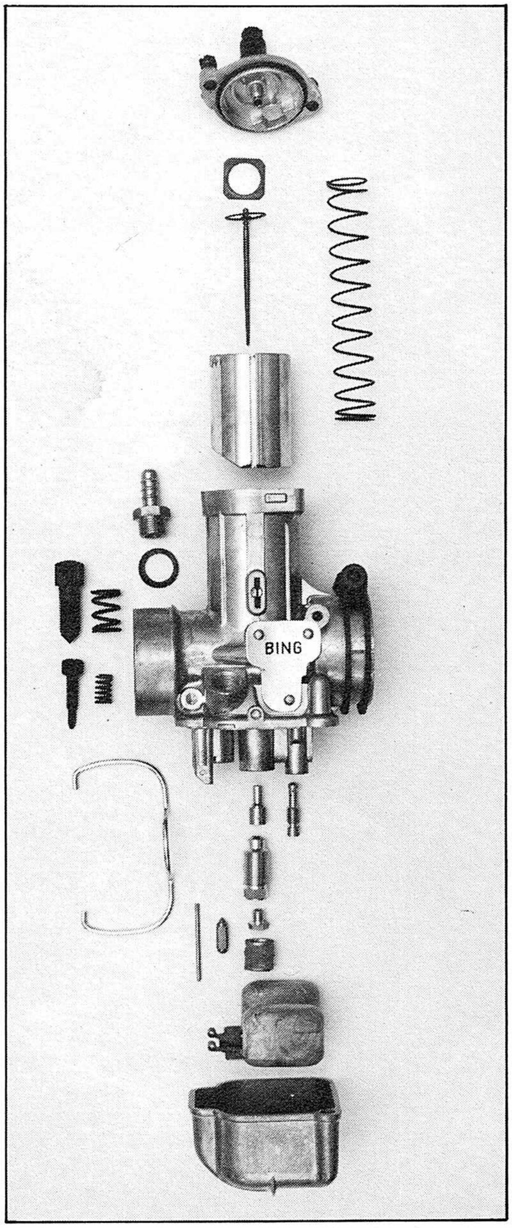
I also questioned Patton about the differences between Spanish and English Amals. You might coax a part or two to interchange, like maybe a slide, but for all intents and purposes you'd just as well think of them as different brands. The metering systems are different throughout and a different set of values has been assigned to the main jets. In the Spanish Amal, the level of the float is adjustable by the interchange of a number of different float needles.

Comparing carburetors also will reveal a number of variances in the way float bowls are attached and in their relationship to the venturi or "throat" of the unit. Triumph's Bob Ellison commented that the "concentric" design of recent years has proved most efficient because it spotted the bowl in line with and directly beneath the throat. The earlier "monobloc" carburetors featured float bowls located to the side. If, for example, the bowl was on the right, leaning the motorcycle to the right as when accelerating through a long, sweeping bend in road racing, would cause a too-lean mixture. Conversely, a similar maneuver to the left would produce an opposite effect. Sensitivity to acceleration and deceleration likewise is minimized with the concentric float bowl location.

Inside the float bowl we run into another difficulty that seems to exist to some degree in many situations where extremly rough riding is done. Here the problem can be intermittent engine starvation that is caused by fuel "slosh" within the bowl. Mikuni's response has been to incorporate a bell-like baffle into the bowl while Bing carburetors feature a screen and Amal suggests that the main jet access plug on the bottom of their late float bowls will extend up inside far enough to provide sufficient baffling to counteract slosh. Still another maker suggests that if the float is the right weight it won't get to shaking

BING





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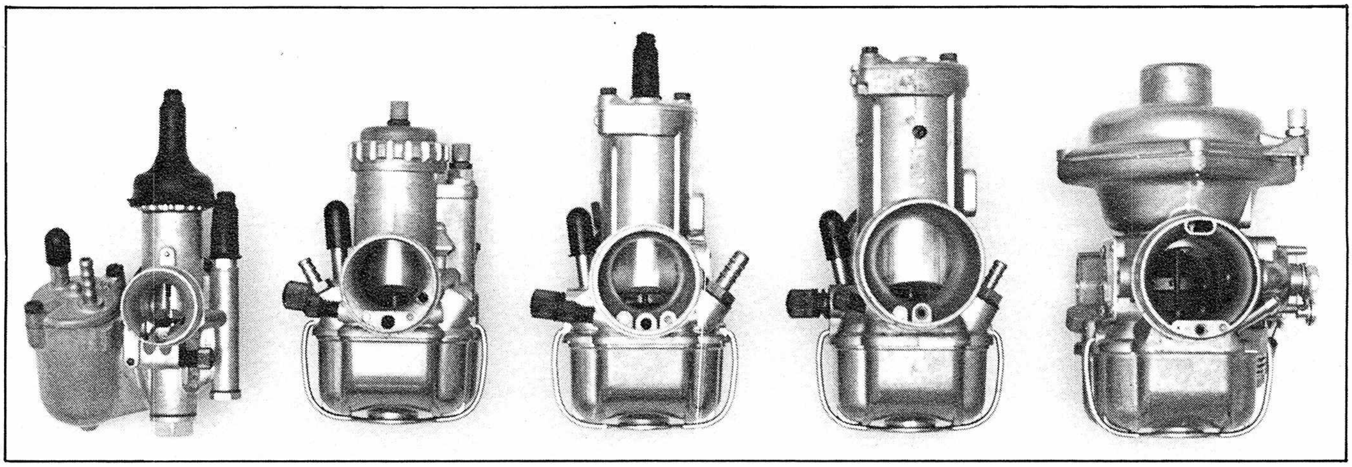

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1) As long as we're counting parts it is fair to observe that Bing comes with only nominal assortment of components. Has baled bowl like the IRZ.

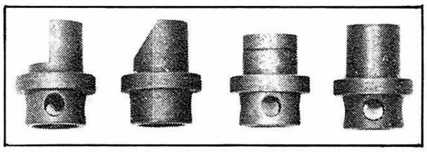
2) Bings crop up like Crosby's sons as line-up includes small side-bowl, three manual sliders and diaphram pumper-slider for BMW at far right.

3) Bing's changeable spray-bar vaporizers enrich mix through mid-range. L-R: Richest, 30° slant for 125 Maico, slightly rich and longest and leanest.

4) Bale is swung aside to reveal recessed bowl gasket and dual floats. Of special interest here is screen baffle around main jet to quell slosh.

5) Bing appears as quality unit with this engine-side look at spigot-and-clamp manifold attachment set-up. Carb can be tilted for bowl access.

6) Size extremes are evident with this view of small vs. large sliders. Small side bowl on carb at left compensates for inclined angle mounting.



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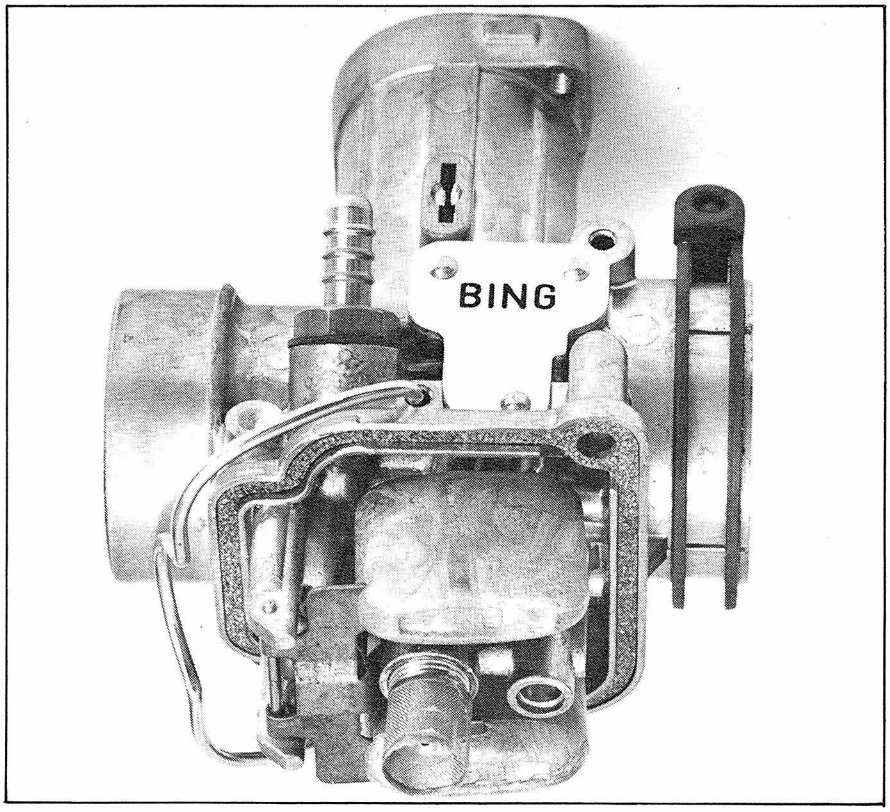

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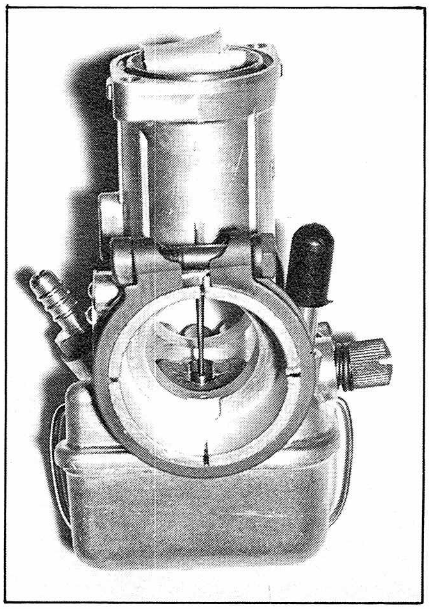

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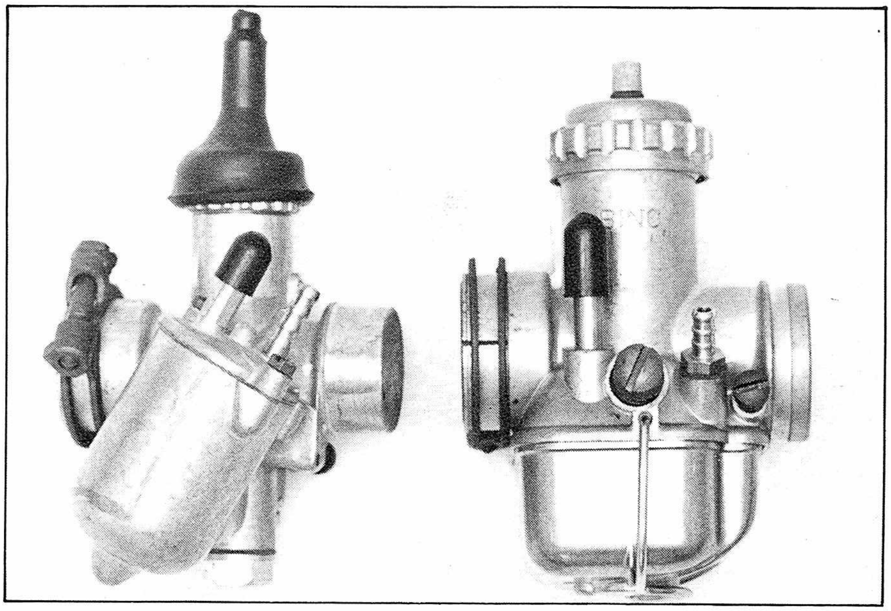

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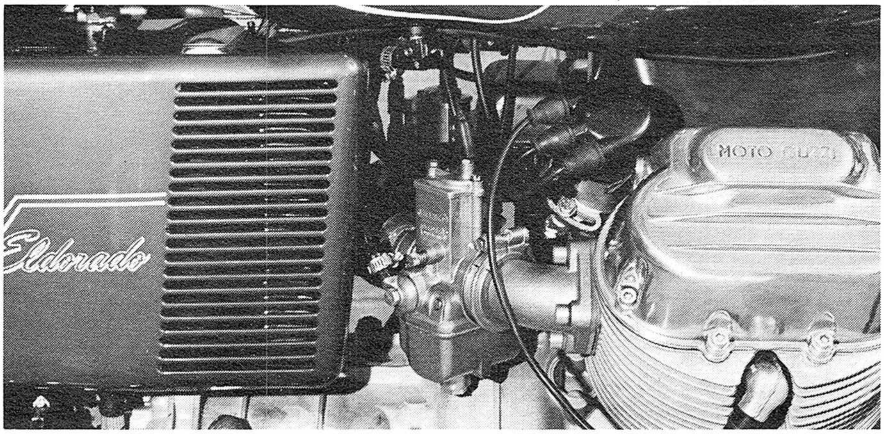
around in rough riding and create a situation that would necessitate the use of baffles. At its worst a problem of this sort would be limited to special situations so if it hasn't happened with your bike don't worry about it. If it has, be assured that something is being done at the factory level.

For all its woes with sticking and wearing slides and float bowl problems, the piston valve carburetor remains one of the most flexible types available today. I've already mentioned the variety of float needles that

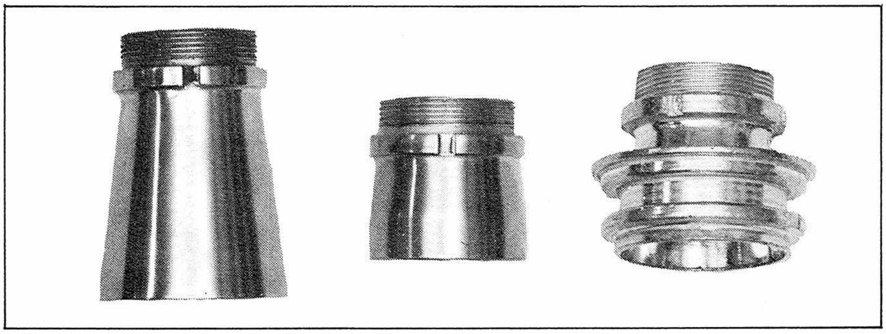


1) Dell Orto spotlights careful and elaborate machine work on their aluminum air cleaner adaptor and velocity stacks. Each fills a performance need.

2) Robust Italian Dell Orto racing carburetors top a pair of so-called "square" sliders used on Moto Guzzi and Ducati motorcycles.

3) "Square" slide can be seen at top of photo just under large slide return spring. Slide is said to give much longer wear, improved performance.

4) Here's that big racing model, somewhat similar to Amal Grand Prix. Note integral float and needle, left. Dual float bowls sometimes are used.



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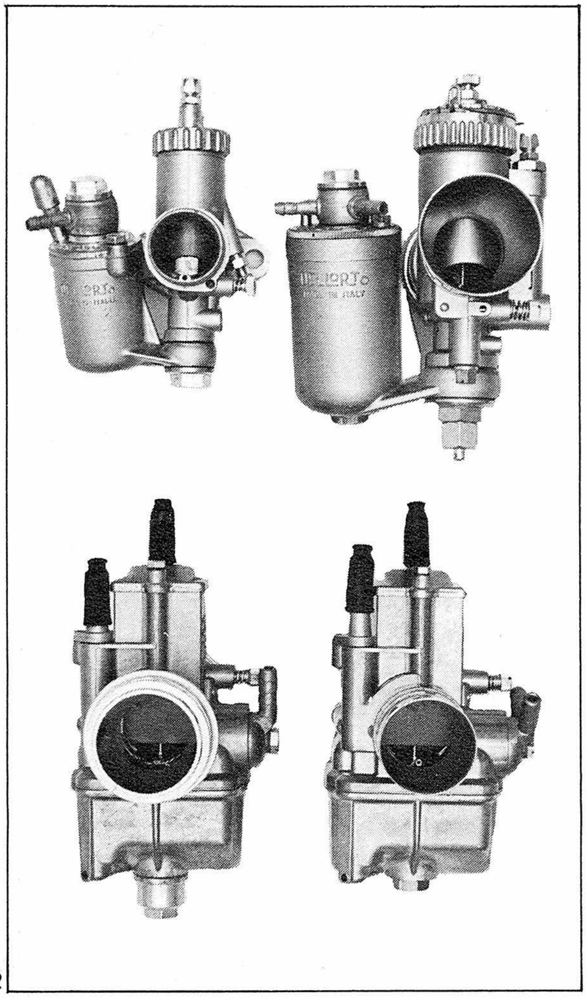

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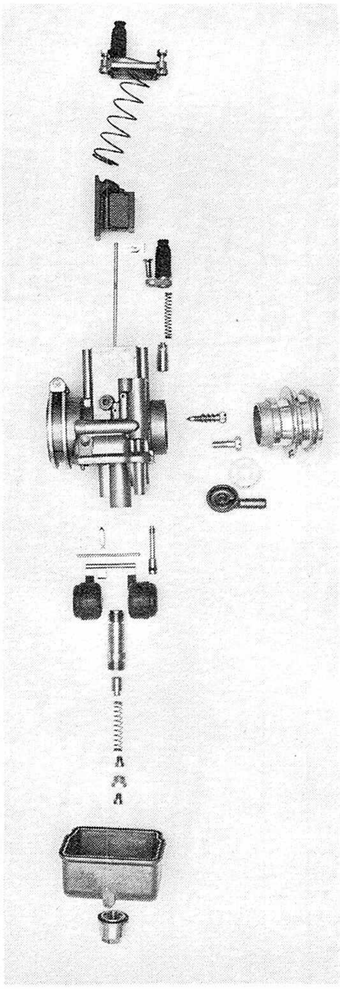

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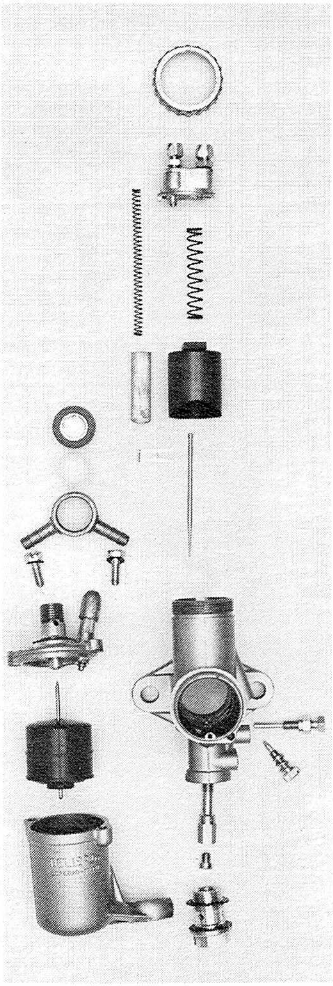

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was talked about by Tom Patton and, as I remember, Barnes Enterprises has an adjustable float needle. Main jets can be had, at least for Amals, in an assortment of sizes that run the scale from gasoline to alky. Pilot jets are replaceable, also in different sizes. Slides, too, come with various amounts of cutaway so that they can be suited to the average altitude of the locale in which a motorcycle is to be used as well as to suit other conditions of operation. Finally, the tapered main jet needle has a set of notchlike grooves near its upper end that provide still another means of adjustment: The higher the needle rides, the richer you'll run. Pay attention to factory recommendations with respect to the positioning of this needle as well as other adjustments and jet sizes throughout the carb.

THE GUILLOTINES . . .

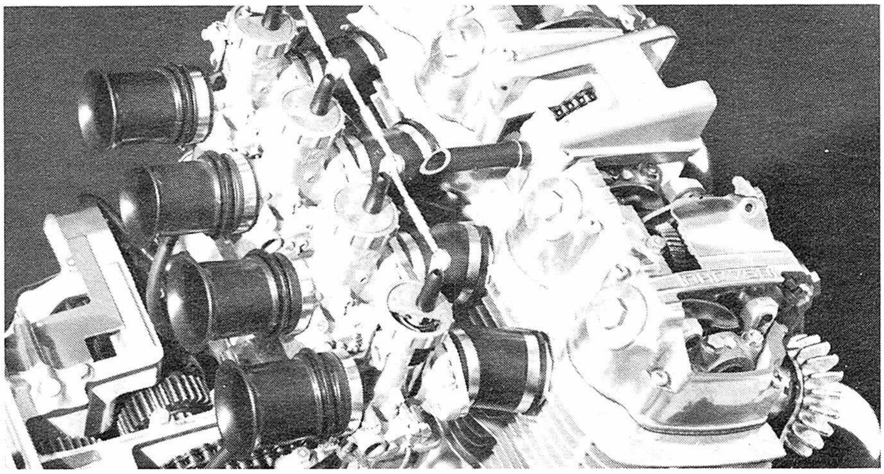
At least two carburetors now on the market are using a sort of up-and-

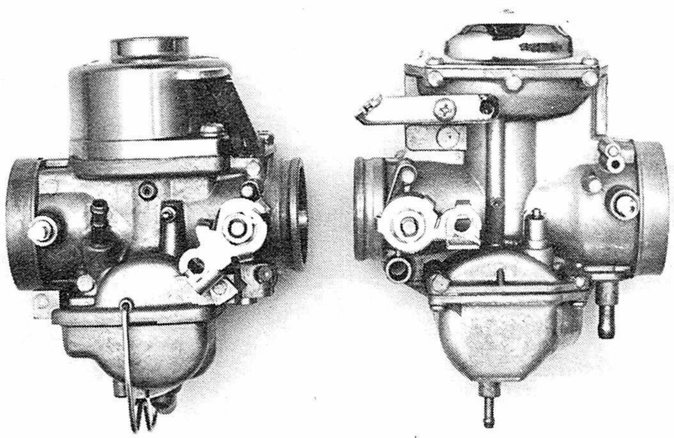
1) Vacuum pulses from engine make these two Keihins work. Left is "no-diaphram" type for Honda 450 while model on right fits 350 street models.

2) Keihin assembly reflects simplicity of concept, is typical of manually operated sliders in line. Main jet and holder are seen under body.

3) In same left-to-right order are 450 and 350cc Honda carbs, open to inspection. Effective seal of large "O" ring, left, is quite critical.

KEIHIN





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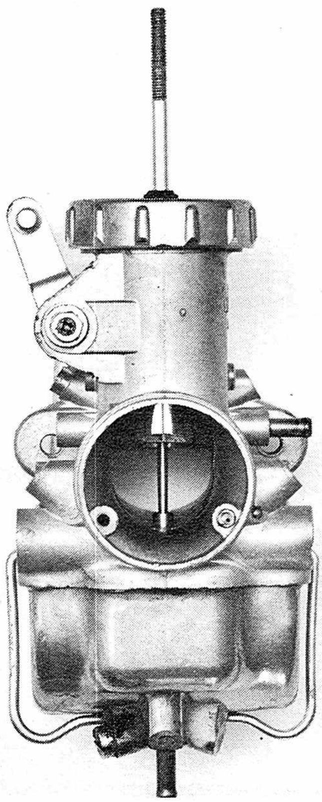

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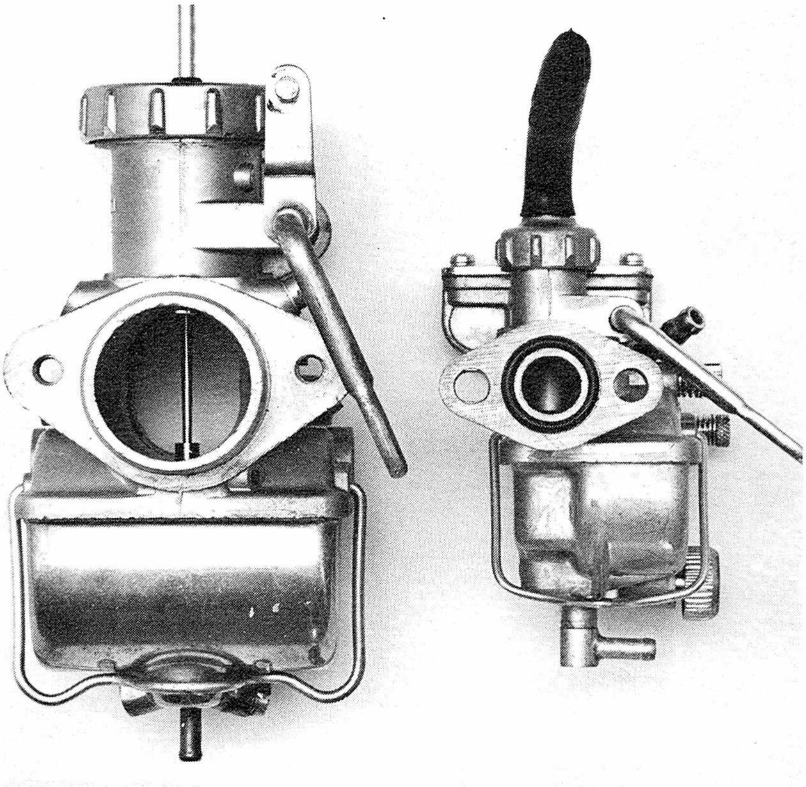

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CARBURETORS

down slide that resembles a guillotine. These units, the Lake "Injector" and the Posa-Fuel, embody the simplest possible approach to delivering a combustible vapor to the cylinder. A first-impression glance at one of these things when it's disassembled and spread out for photographing immediately gives you the feeling that something is missing. You'll see no bulbous castings with cavernous throating, no bowls or baffles or bells or cups, no diaphragms, no floats and float needles . . . most of it isn't there, but it works!

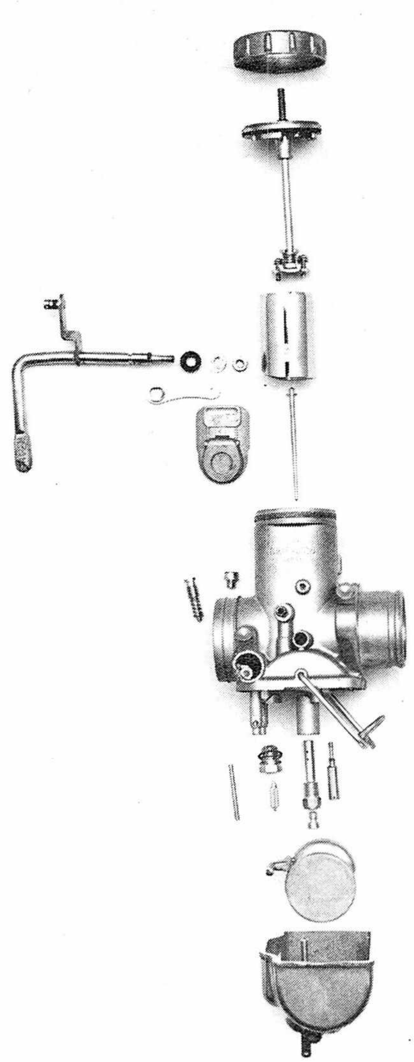
The idea for operation seems even simpler than the carburetor itself. Gravity drops the fuel to the carburetor in the same old time-tested way. A needle, which has been flattened

1) Traction berms on top cap of our carburetor remind us to "hand tighten only!" Never, never use a wrench: An overtightened cap warps carb body.

2) We get a closer look at nomenclature of Keihin for Honda 350cc CB and CL street bikes. Off-road 350 SL uses simple manual slide-type carb.

3) Extremes in size are emphasized as we also notice "O" ring flange seal on smaller carb. Model at left combines flange and spigot systems.

4) The lid's off both the 450 and 350 Honda carbs and you can see both slides with flexing diaphram on right. Slide on 450 is of gravity return type.



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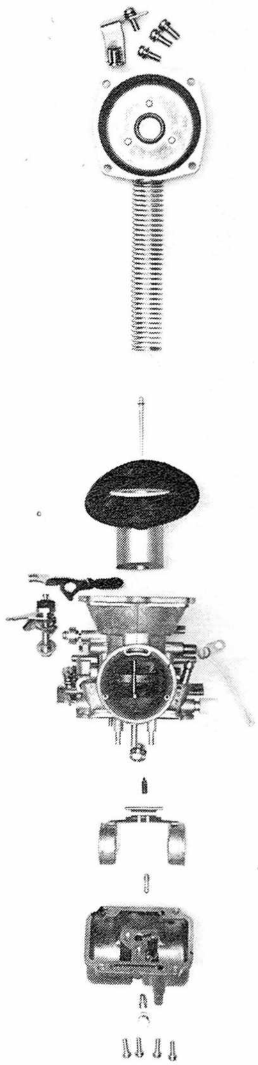

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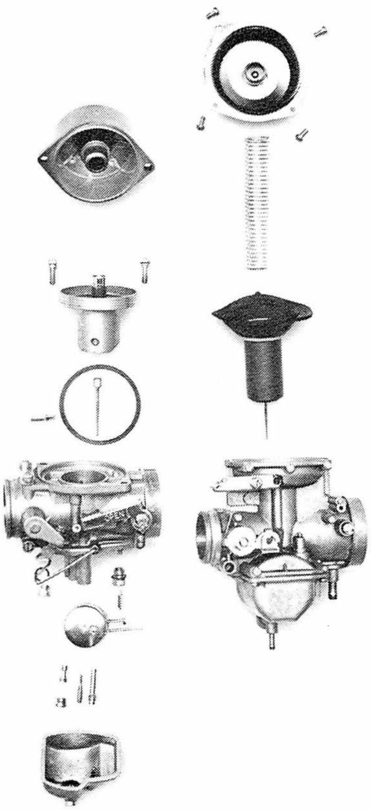

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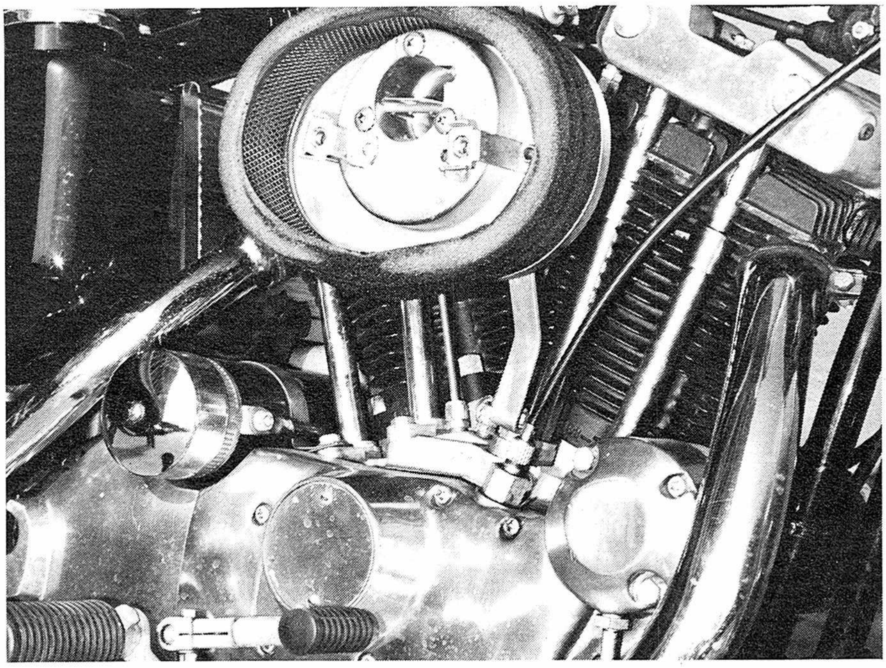
on one end, moves in an orifice in such a way as to control the amount of fuel that is drawn into the cylinder. The throttle is turned, the cable lifts the "blade" and engine speed increases accordingly.

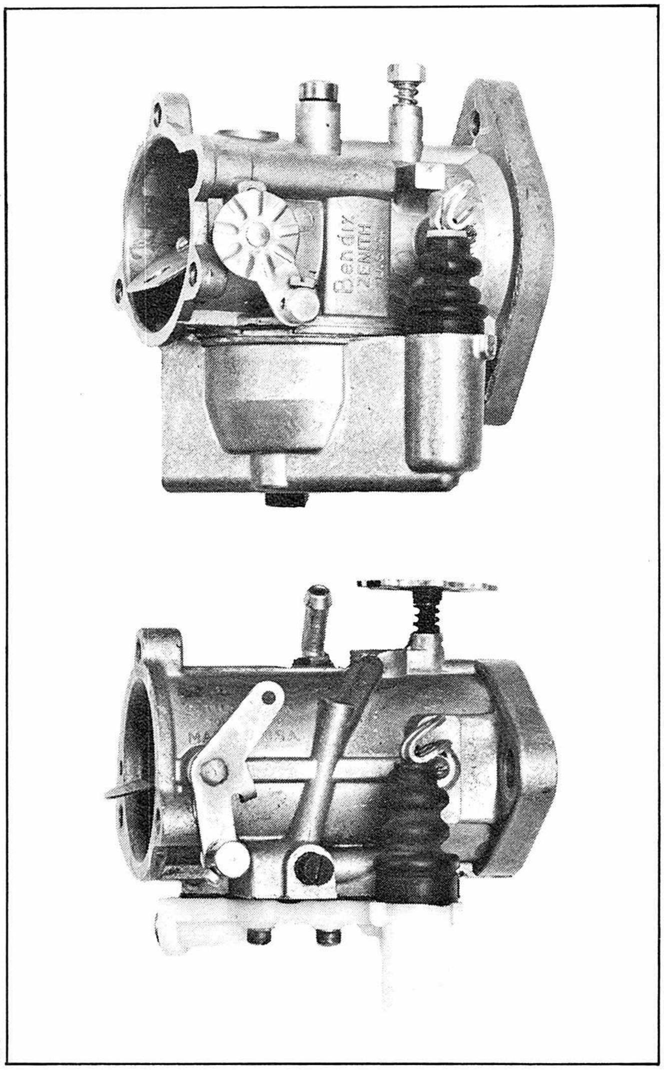
What apparently happens obviously is more exciting than talking about how these "guillotines" work. For example, a letter of testimony addressed to the maker of one, the Posa-Fuel, states, "The performance of our machine over a track ridden only the week before was nothing short of fantastic." The writer, parts manager for a western Chevrolet dealership, goes on to indicate substantially better throttle response—especially through the mid-range—and a marked increase in power. Another testimonial for the Lake product extols such

1) Twin-butterfly, venturi type Bendix-Zenith carb (top) has now replaced auto-diaphram Tillotson on big H-D. Both have accelerator pumps.

2) Tillotson at left has "bullseye" venturi, no fuel bowl, while Bendix-Zenith is less exotic carburetor, representing a return to basic carbs.

BENDIX-ZENITH TILLOTSON





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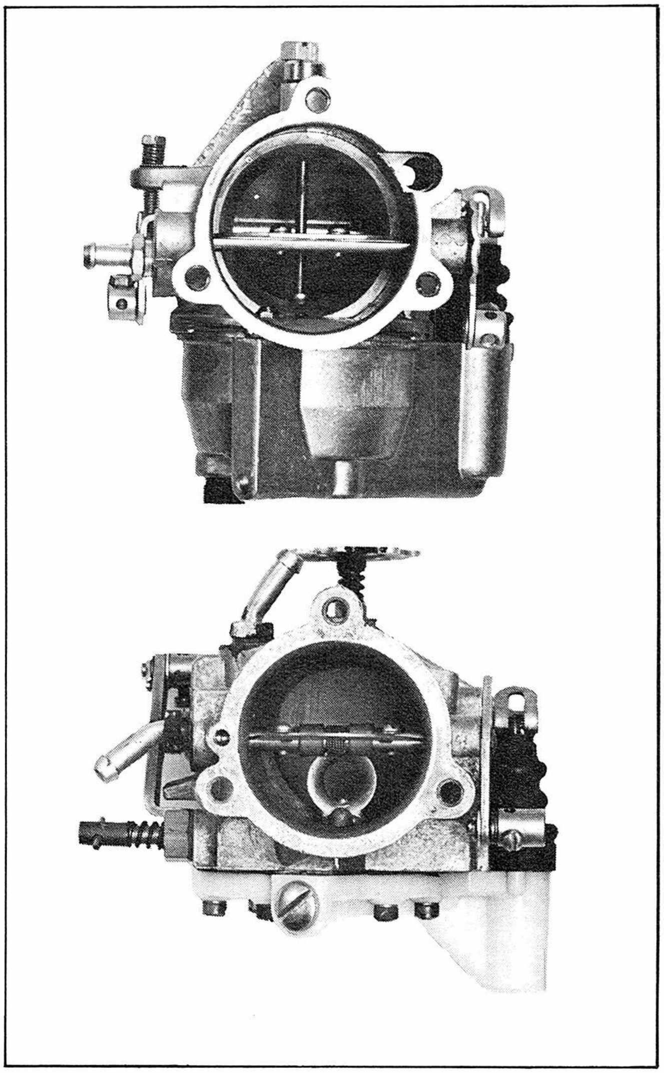

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benefits as a surprising increase in power and performance smoothness.

Full instructions on how to get along with your "guillotine" come with either make. Actually, there isn't much to it since the adjustment is so easily accessible you can virtually effect richness changes—such as might be necessitated by a substantial change in altitude—as you ride along. Getting along might also include such thoughtful details as not forgetting to turn off the tank petcock when you arrive at your destination and not letting anyone ding around with your throttle grip when the engine isn't running. It's easy to see that a gravity-fed carburetor with no float-needle shutoff provision would tend to flood with a little playful grip twisting.

There's nothing in anybody's rule book that tells us motorcycle carbu-

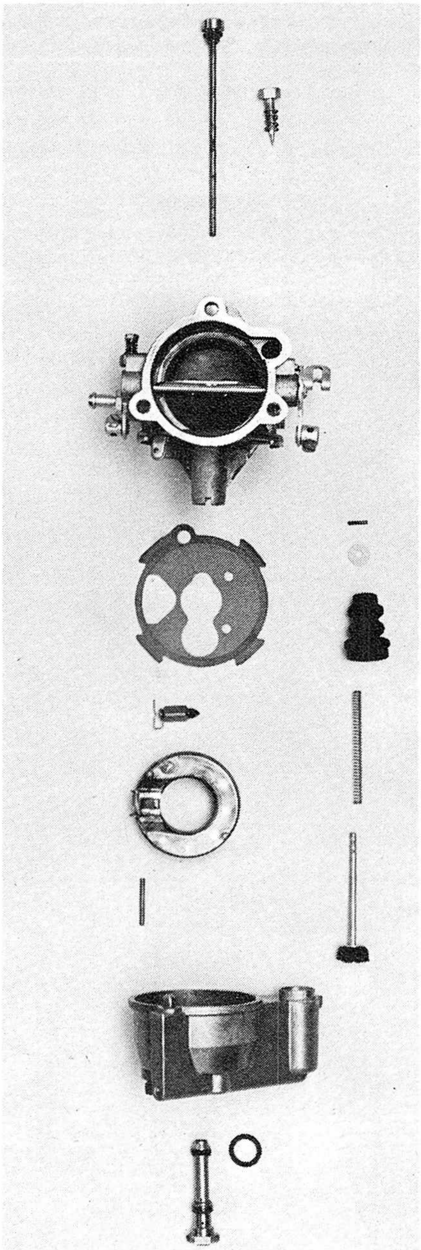
1) The Bendix-Zenith as fitted to new H-D 61 and 74 cu. in. models is updating of old Linkert idea with the exception of its accelerator pump.

2) B-Z for H-D has discharge tube extending into fuel bowl. Tube takes fuel up to both idle and high-speed circuits. Accelerator pump at right.

3) Zooming in for macro-shot of accelerator pump plunger, we see three holes at top for adjusting plunger's stroke. How fast do you want to go?

4) Clip on end of needle valve engages tab on float assembly in B-Z carb, shown here with pivot pin out. Discharge tube is at center of float.

5) Tillotson from underside with metering needle and lever removed for inspection. Diaphram exerts pressure on lever to meter fuel into venturi.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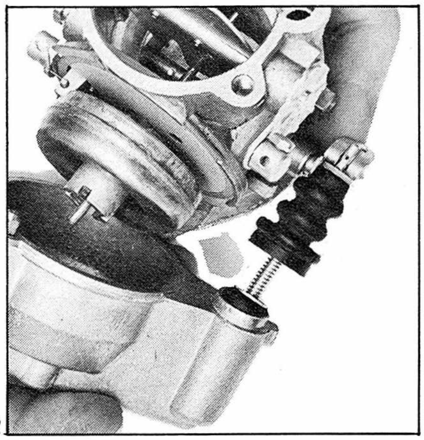
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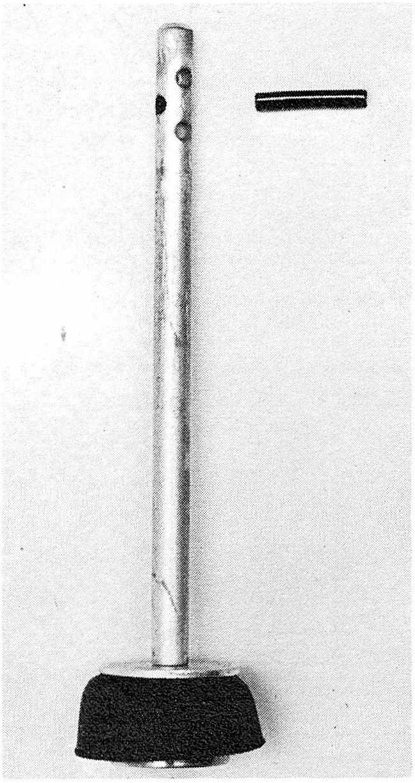
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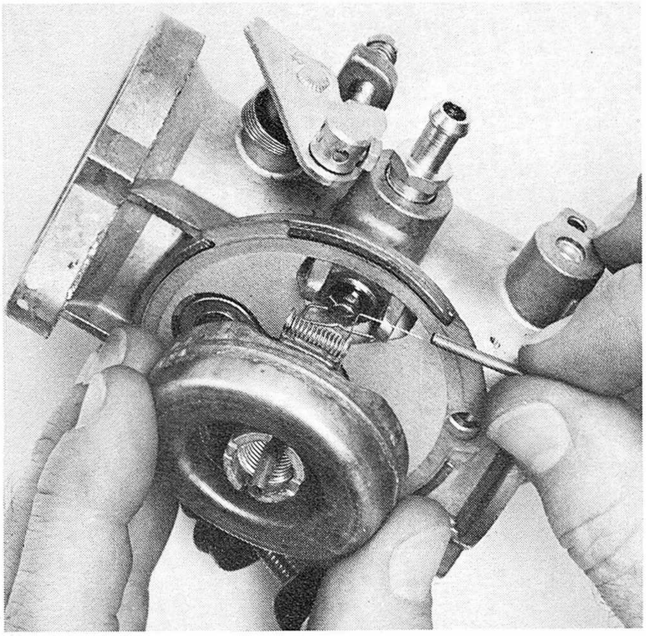
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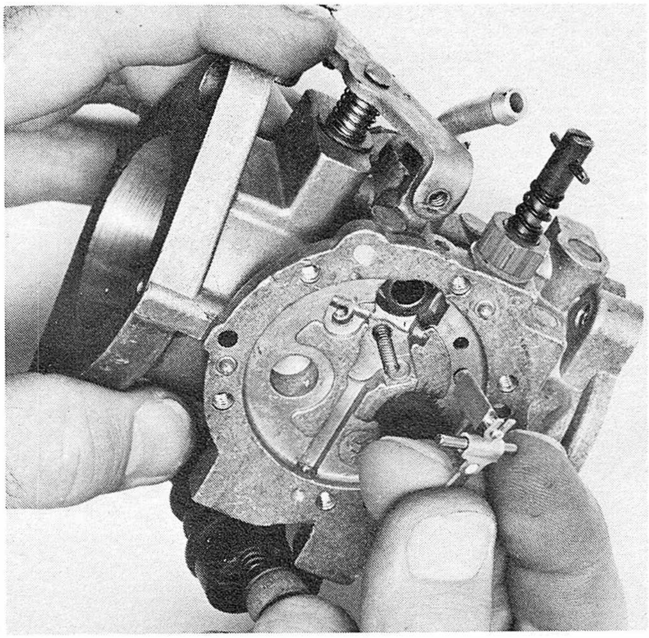
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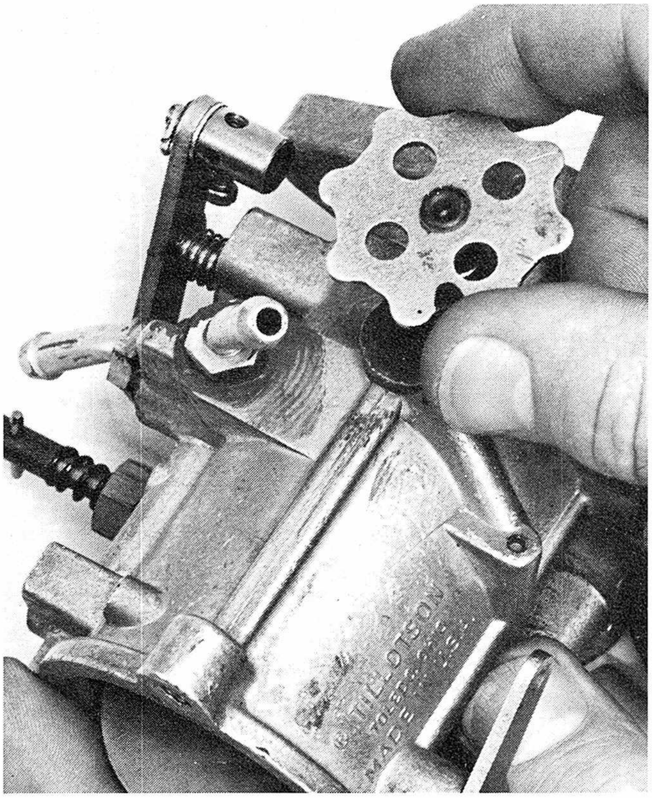

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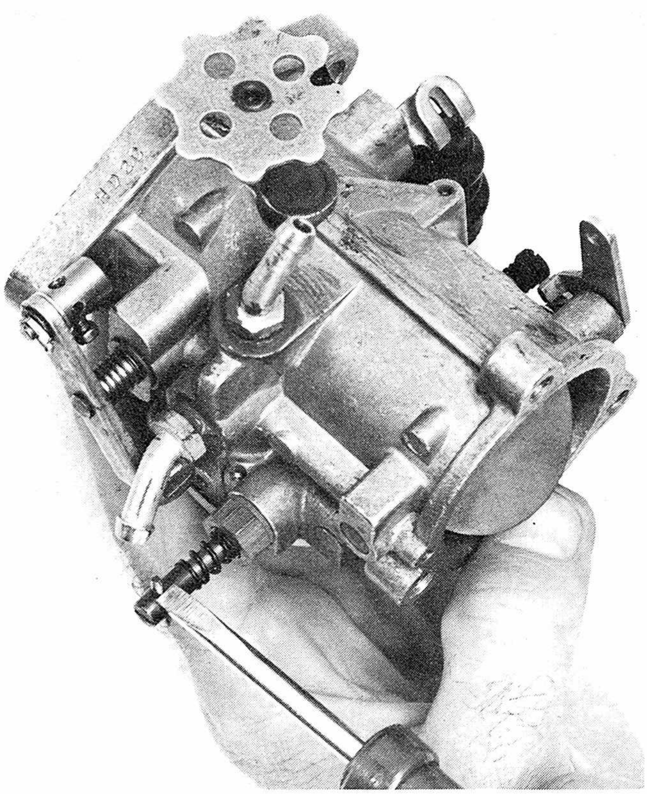

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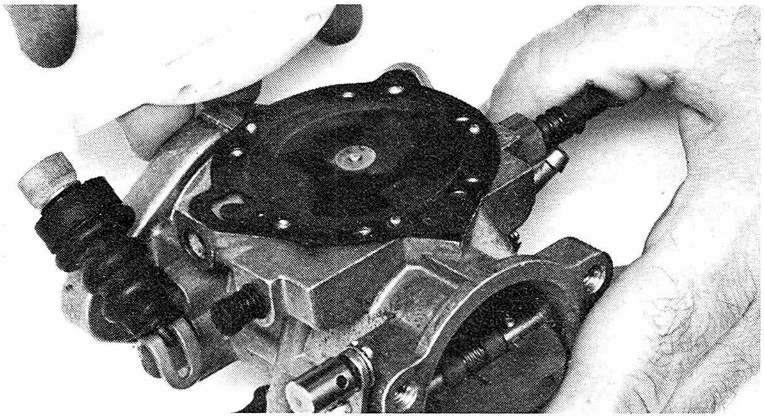
6) Flower shaped disc atop Tillotson controls idle mix adjustment by regulating fuel through idle discharge port. Adjust by ⅛th turn increments.

7) "Big T" has T-bar fingertip adjustment of main fuel jet. Tube on side is inlet with vent tube on top.

8) Bottom cover of Tillotson is off for shot of diaphram. Cylinder for accelerator pump is integral with cover. Butterfly is in open position.

9) Mag-charged twin "shovel Head" Harley big-inch engines are fed by a pair of out-sized butterfly-type S&S carburetors for custom applications.



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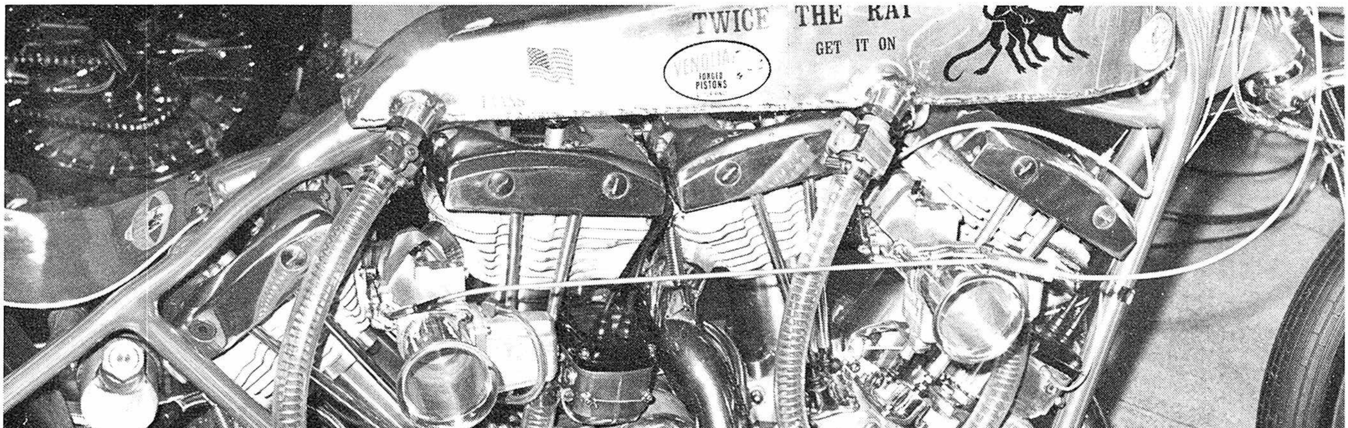

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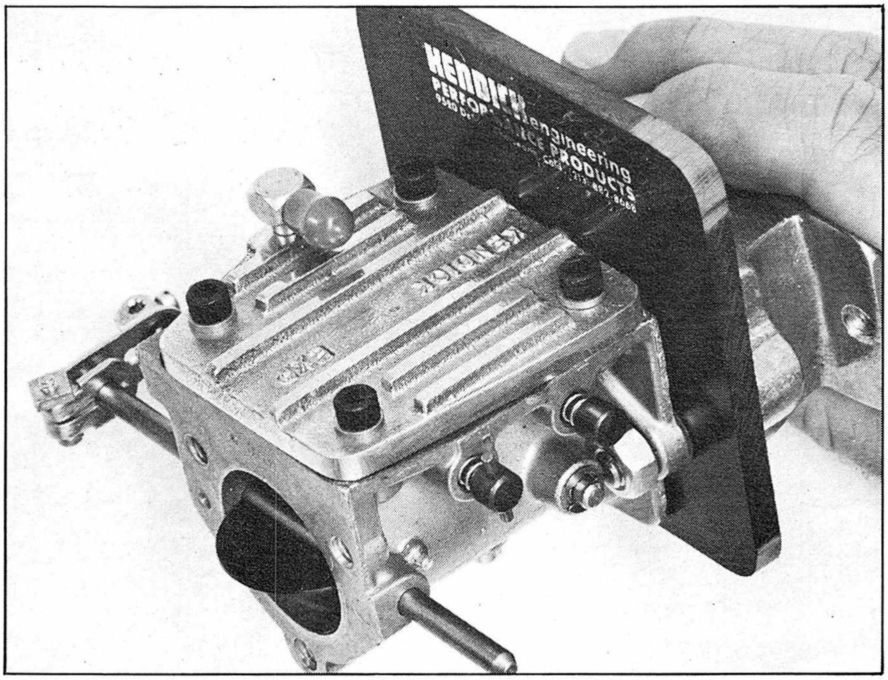
retors have to use air intakes that are controlled by slides. The old-time stove-pipe flue was successfully controlled by a pivoted disc for years; maybe that's when they first called it a "butterfly." At any rate it does the job admirably and actually is used to help introduce some refinements into jetting. In this application, the disc can be used, not only as a means of controlling air volume, but also as a means of controlling minor jet orifices as its edge moves back and forth along the inner surface of the venturi. Jet emissions for smooth stage-to-stage transition during acceleration can thus be released into the mainflow to the engine or withheld, all according to what optimum engine performance calls for.

Butterflys are where you find them, which is just a way of saying that carburetors having this flat, pivoted disc venturi control are of different types. Principally, the types would include carburetors with float bowls and those which had no bowls but, instead, took advantage of a diaphragm. Since the bowl type is the simplest we'll take a look at it first.

Names like Linkert, Bendix-Zenith and S&S come up when you approach bowl-bearing butterfly carburetors. The Linkert, of course, is associated primarily with Harley-Davidson a few years back and actually has

KENDICK PUMPER



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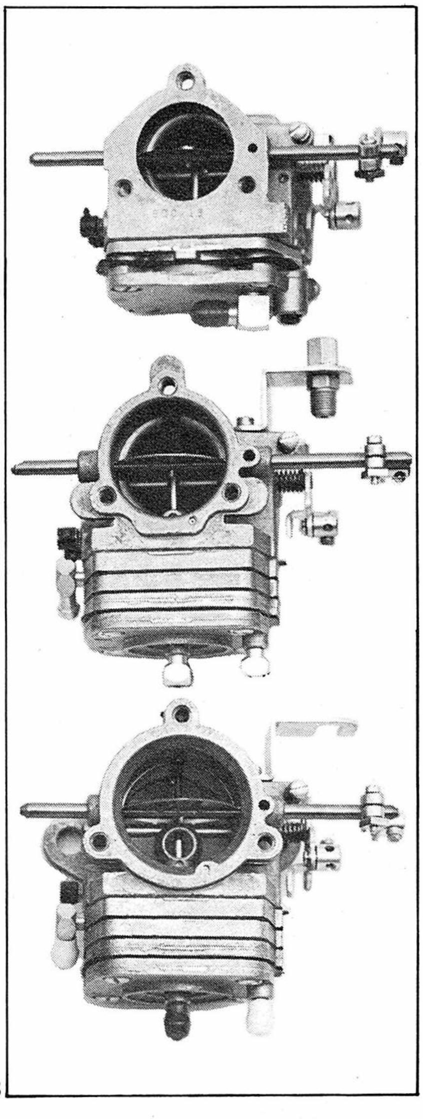
1) Machined, non-conductive shield isolates carb from engine heat. Vibration not as great an influence on this carb with no fuel bowl and float.

2) Custom Kendick carbs provide a look at pumper type (right) and non-pumper on left. Simpler model on left, the "EXP," supersedes pumper.

3) No-bowl diaphram carb, left, is compared to a couple of bowl-type pumpers. Simpler version is said to be free of fuel pressure inside chamber.



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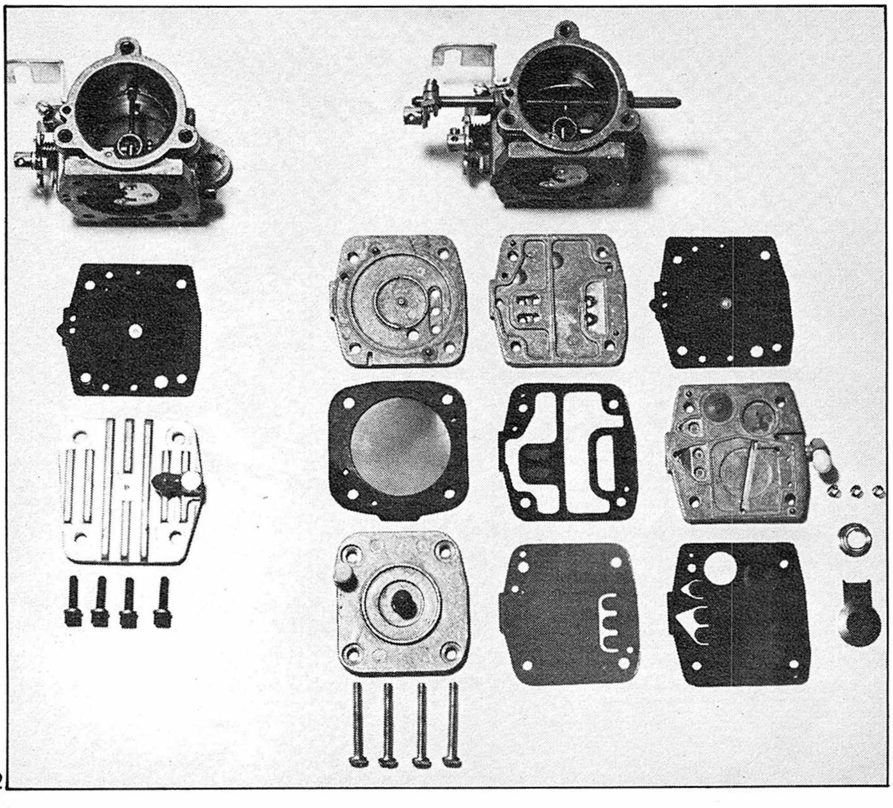

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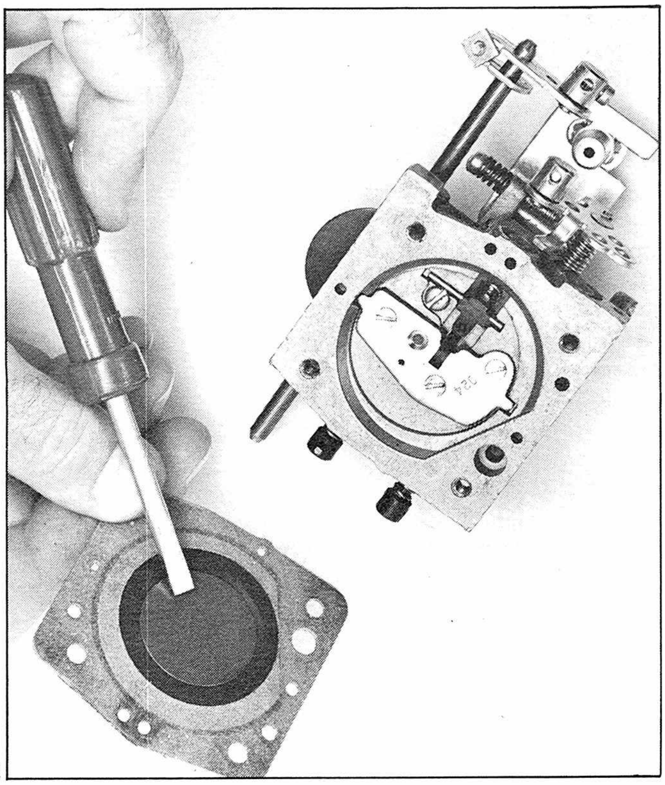

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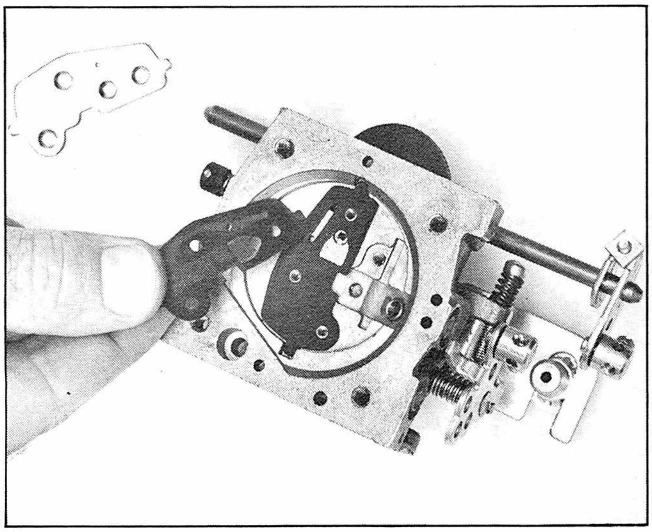

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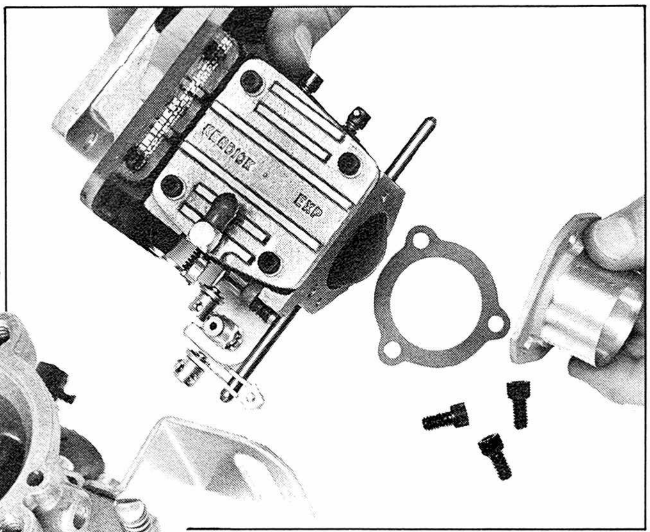

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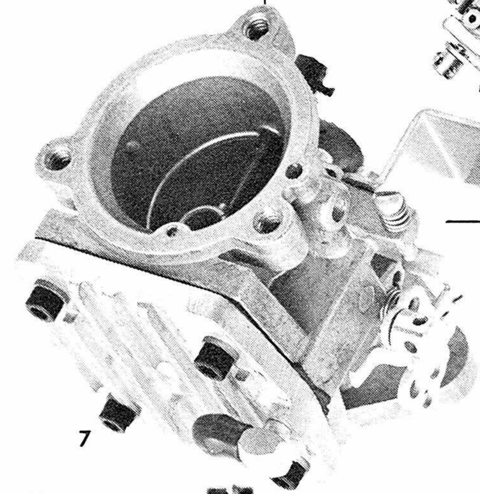
4) Plate on diaphram in new "EXP" is designed to press on metering needle actuating lever, seen on underside of body as throttle butterfly is opened.

5) Circuit plate off showing two gaskets over check valve in Kendick "EXP." Valve controls high-speed jet. If one gasket out, high-speed is too lean.

6) An air filter can save engine from damage under conditions of heavy dust. Kendick has a machined adaptor for purpose of attaching a filter.

7) Throttle linkage on "EXP" is adjustable for quick, intermediate or slow ratios, any cable will work. Idle is controlled by adjustment screw.

8) Fully assembled and ready to bolt on is "EXP" with velocity stack. Carb kit can be furnished for most makes and models. Note adjustable linkage.



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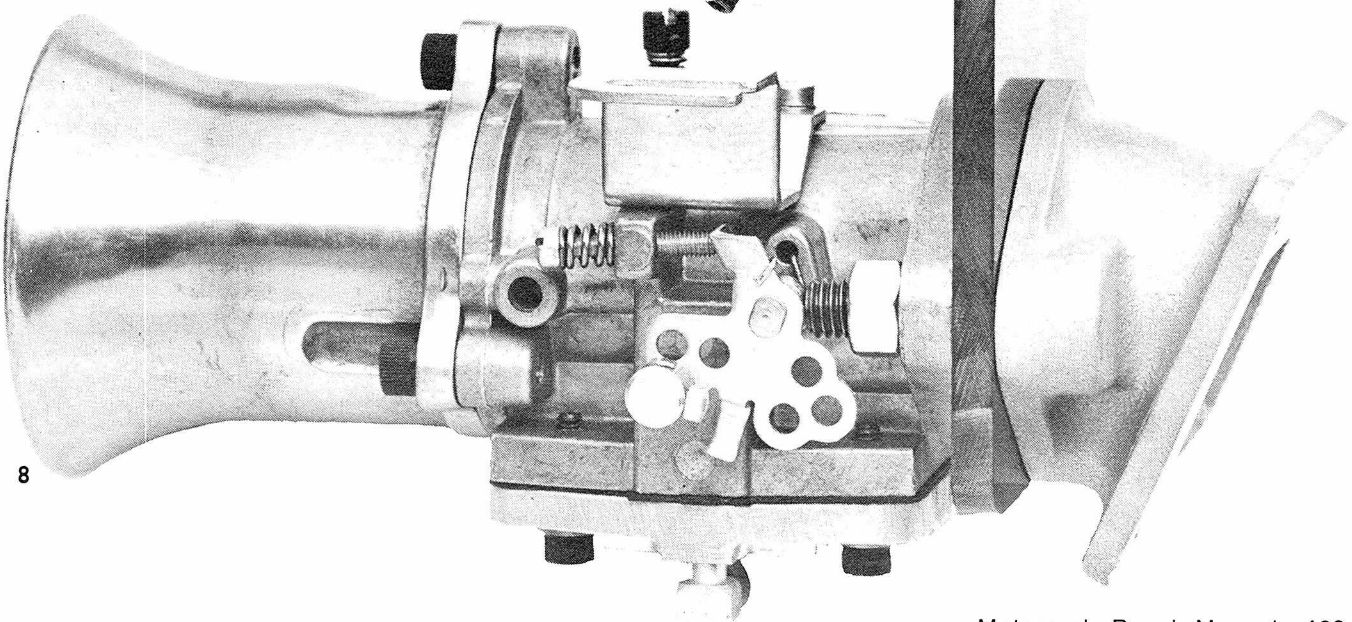

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two butterfly discs, one to act as a choke, the other for throttle control. High- and low-speed needle adjustments angle in from the topside of the Linkert and present a quick and easy means of adjustment. The S&S is similar in concept, if not in detail, to the Linkert. The main difference lies in the former's greater bowl capacity and larger throating for special application on some of today's maximum horsepower Harleys.

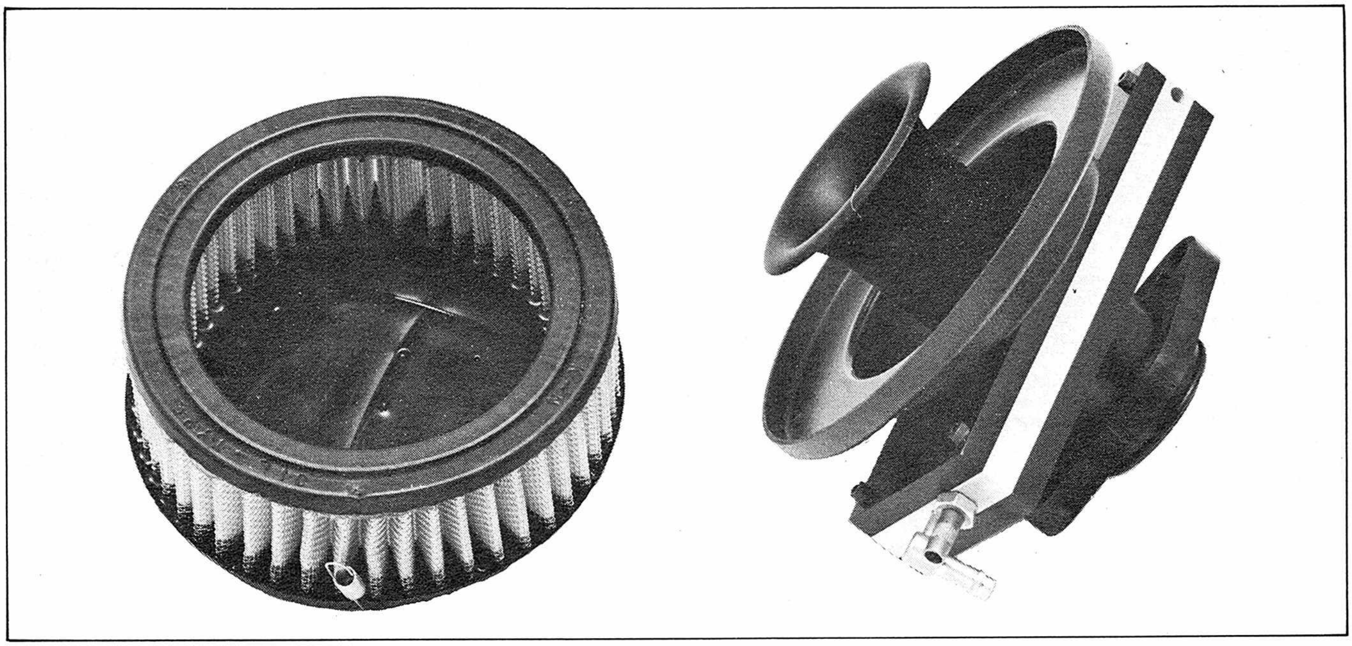
A little more detailing can be found on the big Bendix-Zenith rigs now being employed as original factory equipment on new Harley-Davidsons. The extra attraction here is the addition of an accelerator pump to provide that added mixture richness when sudden acceleration is needed. A small, finger-size plunger pump is included on one side of the carburetor. A quick turn of the throttle sends the plunger downward, applying pressure to a small reservoir of fuel which is supplied through a check valve from the main bowl. The extra charge is then forced up past another check valve and into the mainstream of air-fuel mixture traveling through the venturi. The plunger rod, incidentally, has three adjustment holes at its linkage end so the amount of pump stroke can be regulated.

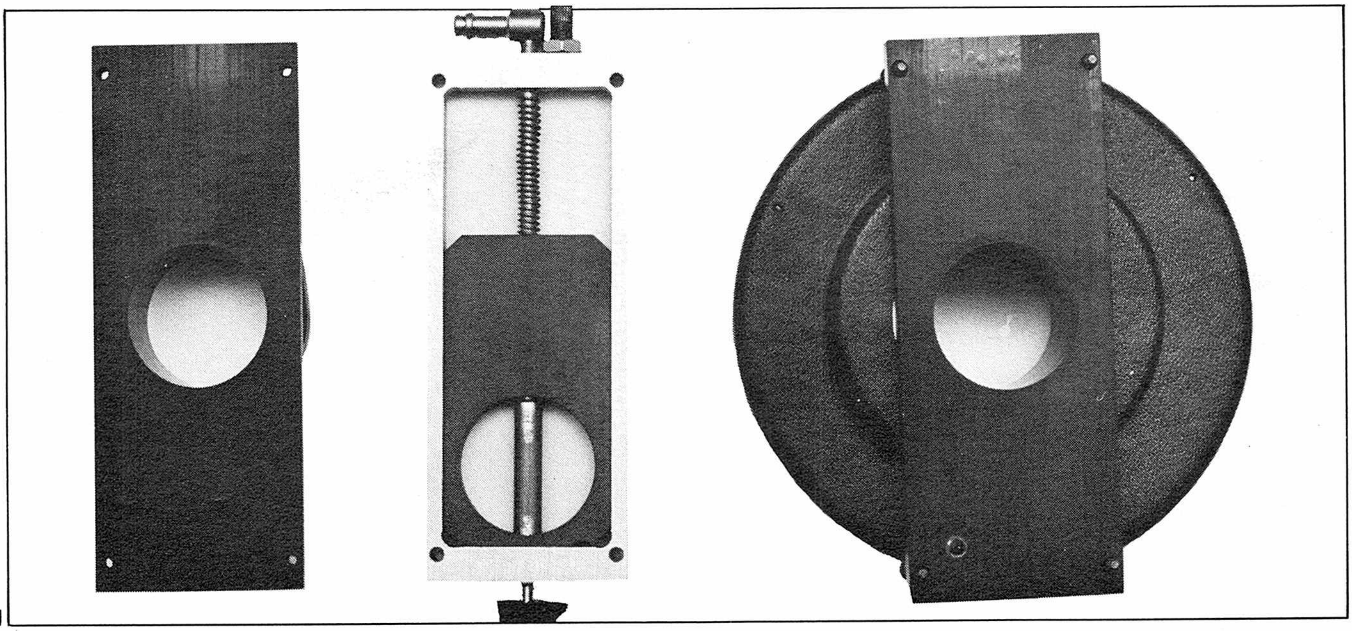
CAME THE PUMPERS . . .

It was inevitable, I suppose, that someone, somewhere would sooner or later come up with the idea that a diaphragm could be acted upon by changes in pressure within the carburetor and, furthermore, that said diaphragm could be counted on to push against a lever that would, in turn, open a valve to the admission

1) Lake assembles and installs easily. Running with or without air filter can be achieved. However, richness of air-fuel mixture requires readjustment.

LAKE





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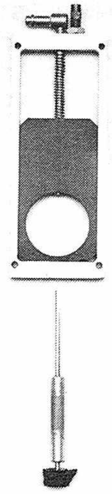
2) Lake's rack and slide are seen with slide in fully closed position. Needle, needle holder and adjustment know have been removed for inspection.

3) Guillotine slide at fully raised position as in full-throttle running. Allows maximum amount of fuel to be metered into mix. Dial knob adjusts.

4) Lake's assortment of needles is not without strange, flattened version at center. Correct needle adjustment at between 9 and 18 turns from stop.

5) Another guillotine carb, this time it's the Posa-Fuel. Larger model can be had with optional idler screw. Polishing also is an appearance option.

6) Posa-Fuel has slightly different adjustment details when compared to Lake version. Also features fully enclose guillotine slide rack casting.



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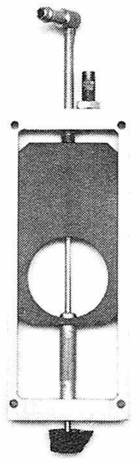

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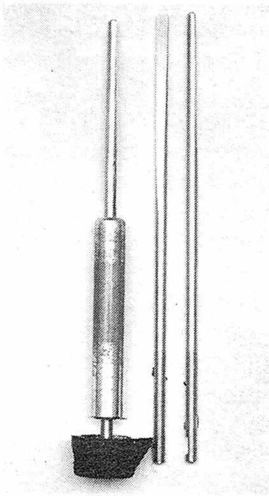

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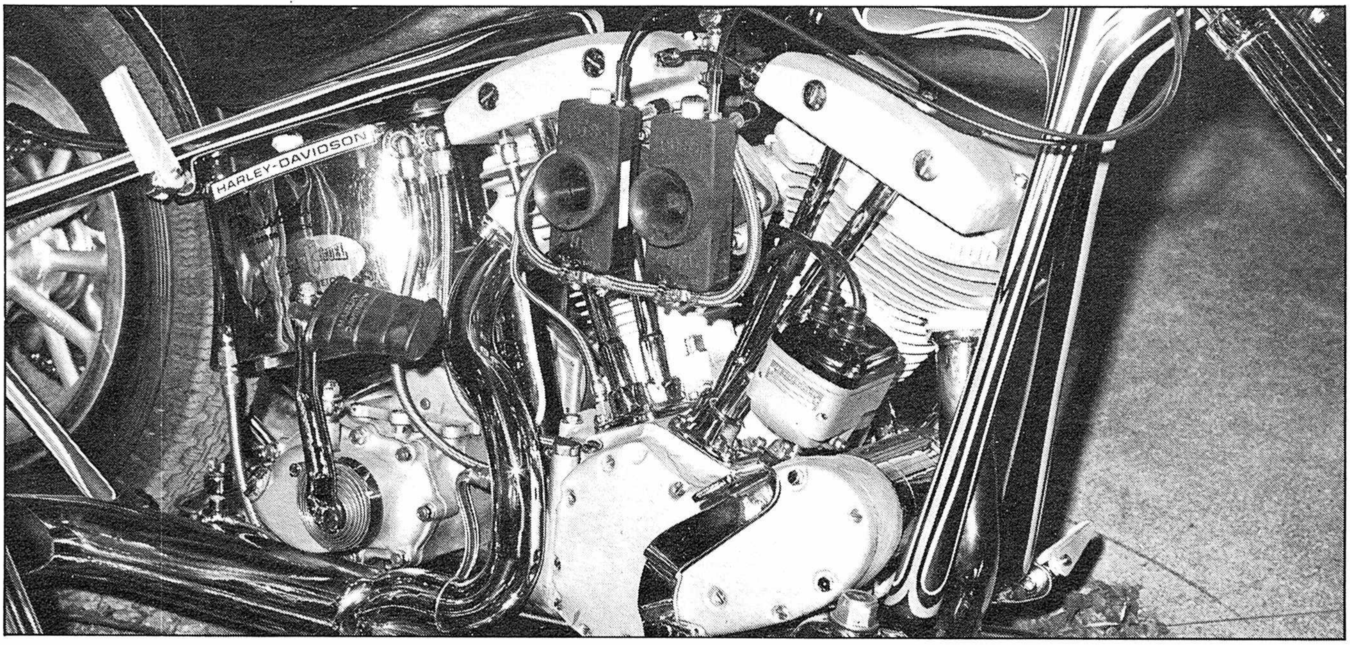
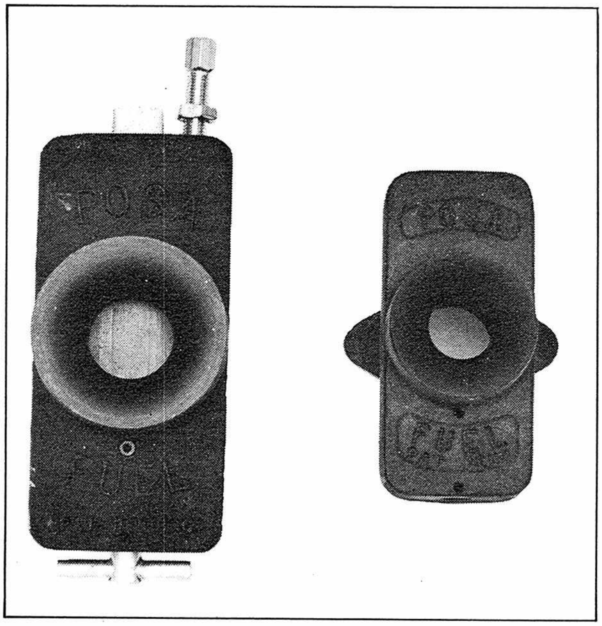
POS-A-FUEL





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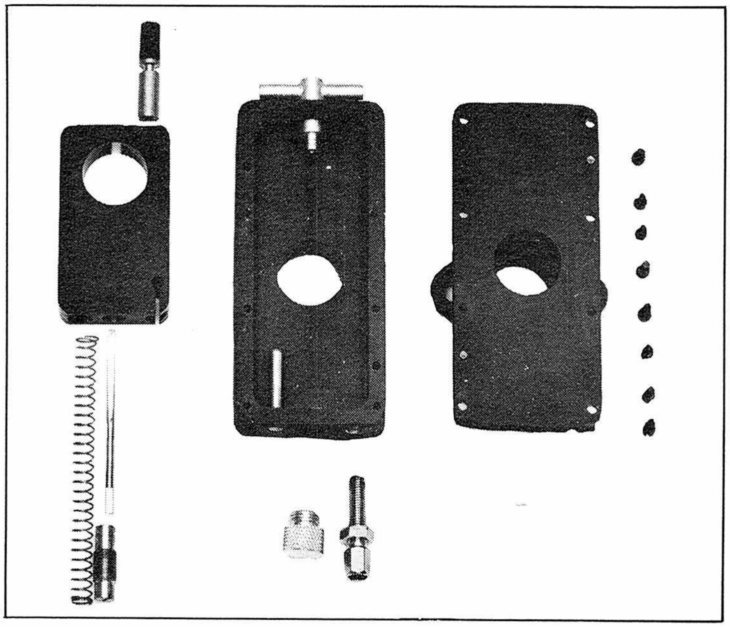

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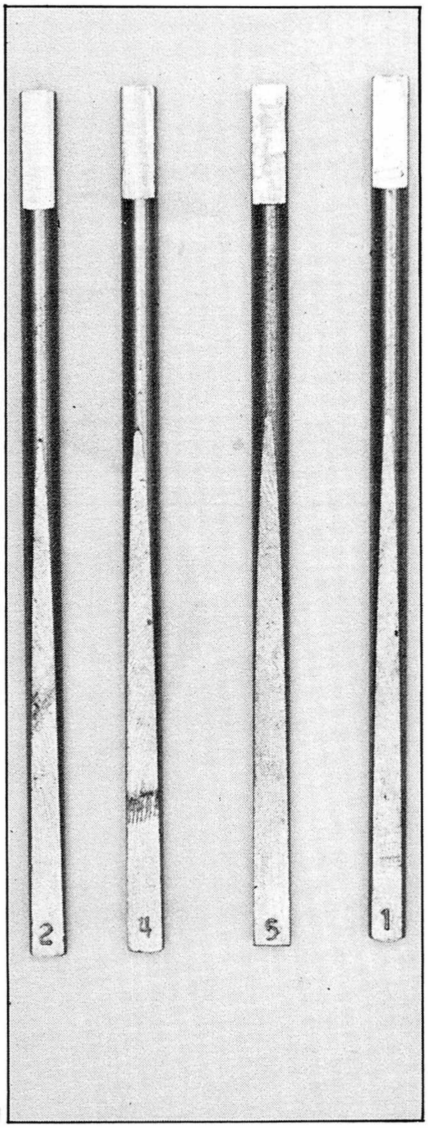
of fuel, and so on. The idea works and, I might add, it works quite well. Since the intensity of pulses from the engine are proportionate to piston speed, hence the need for more air and fuel, both concept and result seem to have aligned themselves.

Most of the people I mentioned as makers of slide-type carburetors also have in their stable at least one model that features diaphragm pumping. Bing, for all its much-perfected sliders, makes a pumper for the BMW. Mikuni has one that's in use on the Yamaha 650 and Honda puts Keihin pumpers on 350 and 450 models and calls them "CV" (constant-velocity) carburetors. Then, to be sure, there was Harley-Davidson's brief romance with the Tillotson a while back. I had no problems with the Tillotson on my Sportster after I converted the choke to a tickler by dangling a rivet through the atmosphere vent on the bottom side of the diaphragm. A push or two on the shank of the rivet from beneath would flex the diaphragm just enough to let a little extra fuel into the venturi for starting. The main trouble seems to have arisen from flooding that would take place when a small particle of dirt from the tank would get into the inlet needle seat.

Adjustment procedure for pumpers parallels other carburetors pretty closely. Each model within each make has its personal idiosyncrasies and you'll find that, even within this chaotic framework, each individual motorcycle will react to tuning efforts in a slightly different manner. There is, however, a correct procedure outlined in the particular workshop manual for your bike. That Nth degree of perfection you're seeking usually won't be too far from the general settings recommended by the factory.

SOMETHING SPECIAL . . .

Before we go on to some tips on tuning and maintenance, there are some special carburetor applications that are worth looking at. Actually, the S&S could have been mentioned here because it's one of those biggies that is capable of supplying the quantities of fuel needed to run super-powered stroker Harleys and other gas locomotives. The custom power boys also are going for the Mikuni Solex, an out-sized, dual-throater taken from the original Weber design. Frank Ryan of Mikuni says the people using them on bikes are probably buying them from Datsun dealers, since Mikuni's motorcycle division doesn't have anything to do with their sale or distribution. Carburetors of this type look good on a bike—they can make one look as if it is about to "stage" for an eight-second run, even if it's only parked under a shade tree. For this reason, I would suspect that, while they are doubtless quite efficient, they are equally cherished for their scarey appearance. After all, looking fast is half the fun!



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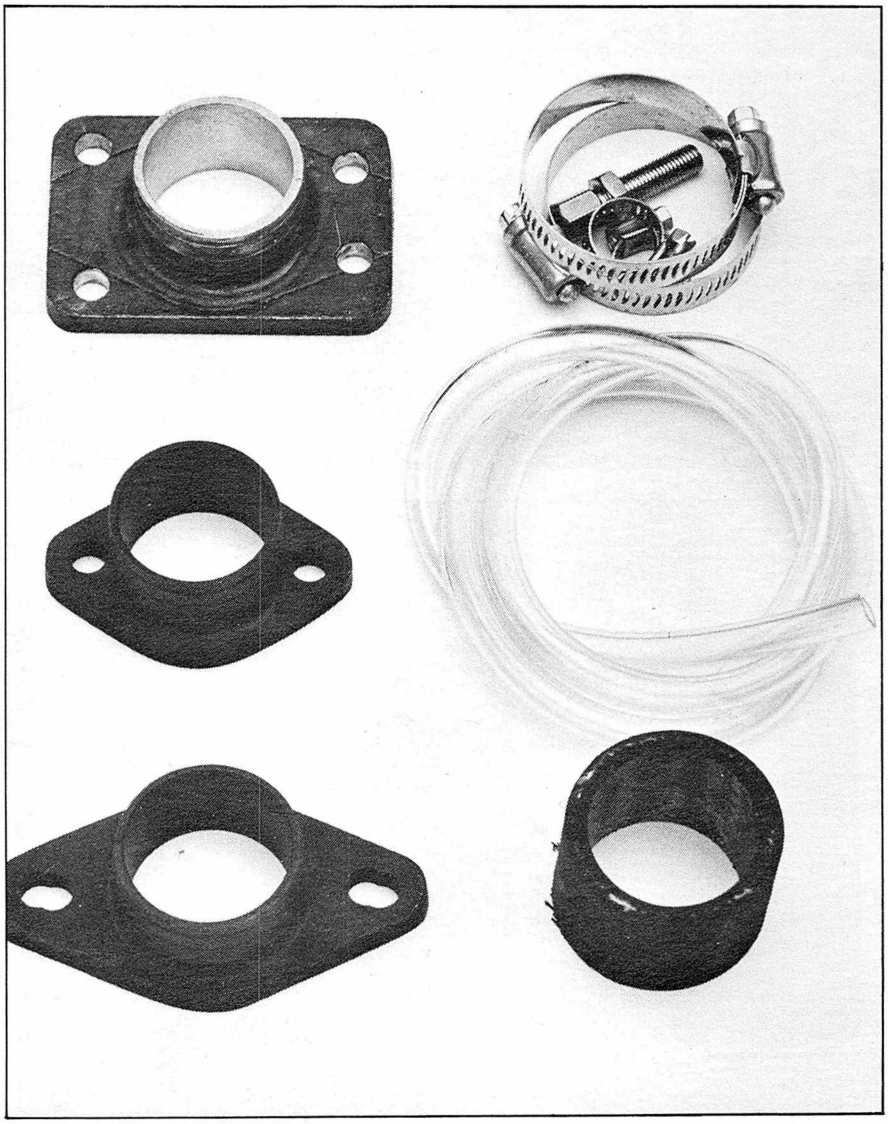

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1) Differences in thickness of Posa-Fuel's various jet needles with higher numbered, thinner, needles giving richest fuel supply at high speeds.

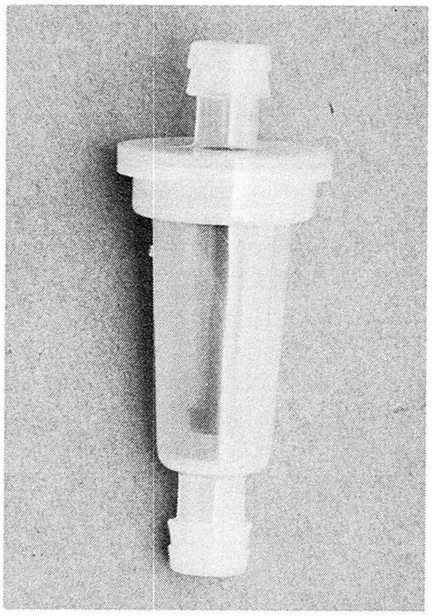
2) Flange and air filter adaptors for Posa-Fuel carb kits are shown. Include transparent fuel line, clamps.

3) One of several in-line fuel filters available. Accessories of this type either trap of screen-filter residue in fuel. Use can be recommended.

4) The heavy grease being applied around circumference of this air filter will help form seal, trap dust particles. Element needs oiling, too.

5) Screen filter opened up to show accumulation of sediment from fuel tank. Particles can jam needles and jets in carburetor and cause trouble.

6) Throttle valve and cut away, jet needle and main jet drawings emphasize importance of cut away sizes, needle adjustment notches and main jet size.



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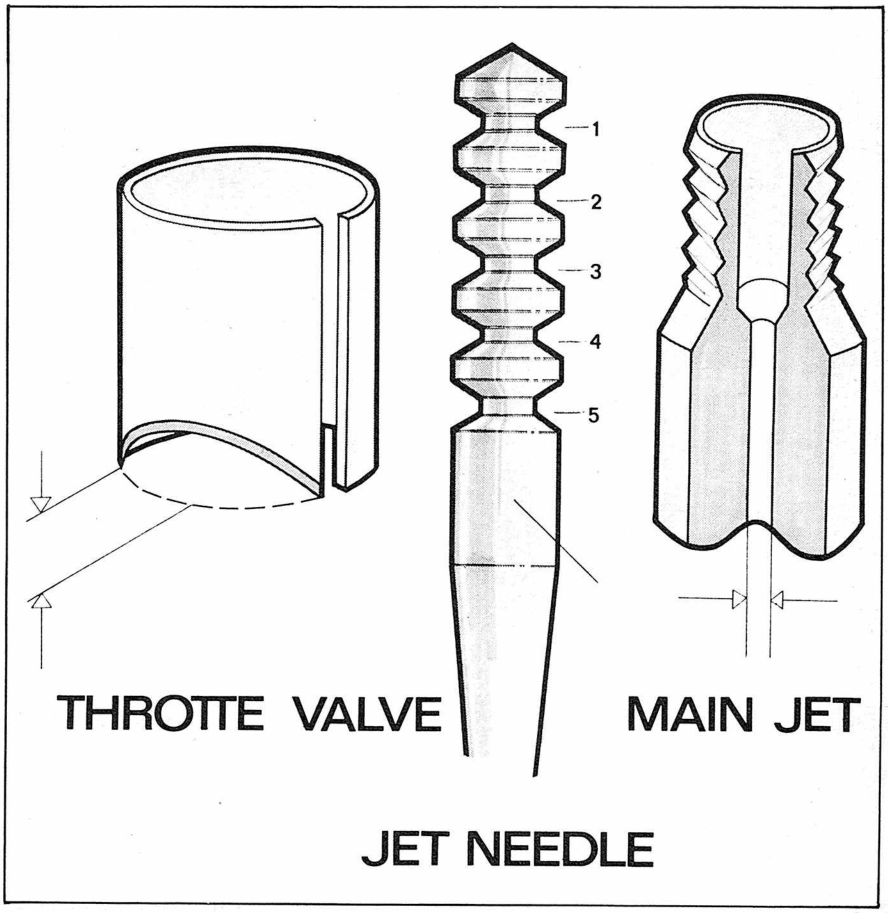

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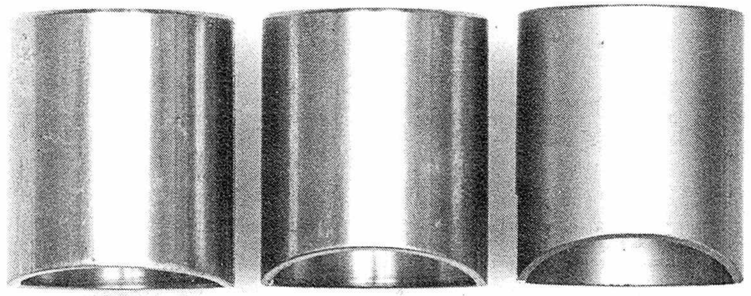
CARBURETORS

The Kendick is distinguished among custom carburetors because it is a simple carburetor that has been redesigned to become even more simple. The pumper model previously offered has had roughly two-thirds of its parts stripped away only to re-appear as a new, improved carburetor called the "EXP." Gravity feed has taken the place of the pumper system. There is no bowl, as such, but there is a valve-controlled metering chamber. Vacuum across the jet, as created by the movement of air through the venturi, actuates a diaphragm which, in turn, moves a needle off a seat and allows fuel into the chamber. The new "EXP" is said to have no fuel pressure in the metering chamber, as with the pumper, with the result that metering at low speeds is less difficult.

We had no sooner set up our photos of the new Kendick "EXP" than Dick Raczuk phoned to say the choke had been discontinued in favor of a "tickler" system. So, if you have a chunk of rubber in your mind, erase the choke disc and imagine a tickler in its place. Three sizes, 29mm, 33mm and 40mm are offered, the latter featuring a "bullseye" venturi so that there's still a vacuum over the main fuel nozzle, even on the low-speed circuit, providing smooth power surge all the way through. A Kendick "EXP" is said to have been set up on a Maico



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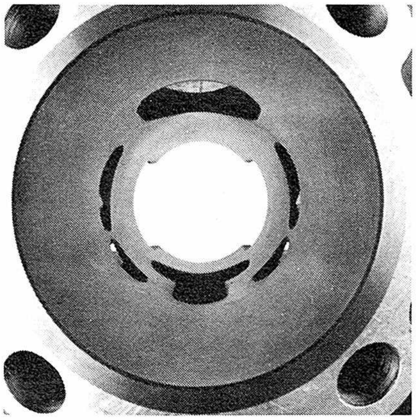

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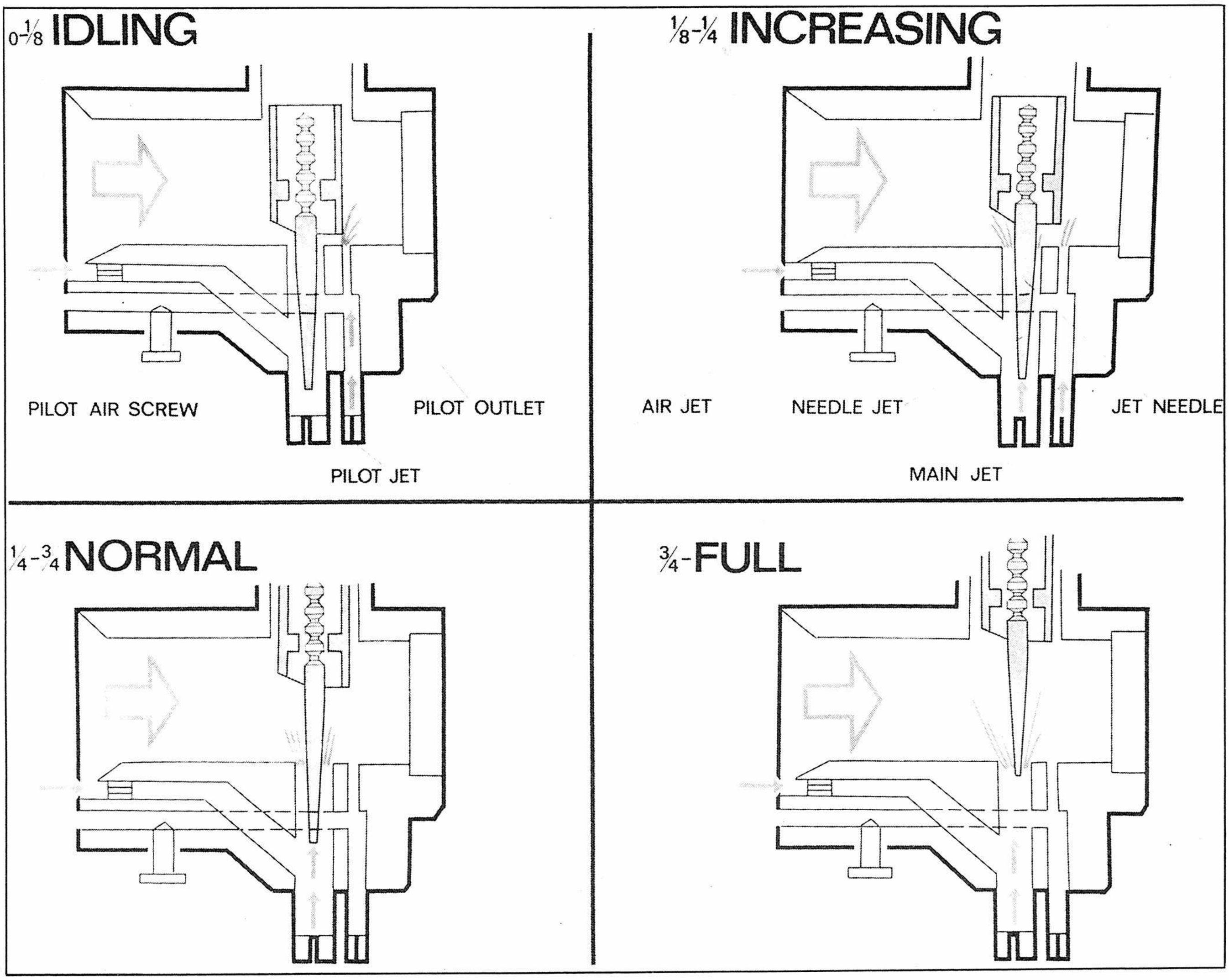

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and run on Axtel's dyno with the result that it pulled a thousand rpm sooner on the low end and added another thousand rpm of pull on the top end! Add to this bounty the extra advantages of claims for instant starting—with the new tickler system—and virtually flood-free operation and the whole proposition begins to look like a pretty fair investment. Like other custom items, the Kendick careburetor comes as part of a kit which is adaptable to your bike. This would include a machined manifold, heat shield, air cleaner adapter and linkage adapter. Raczuk says any throttle cable will work and that a swivel position adjustment lets you have a quick or slow throttle, according to your preference. Get it all together and you'll be able to add a tooth to your countershaft sprocket, the man says.

TAKE YOUR CUE FROM THIS TIP OR TWO . . .

I rambled at length with people in service departments, manufacturers and mechanics for days before I delved into the text of this report. The following is a boil-down of dozens of carefully scribbled notes on carburetor curioso. Dennis Blanton at American Honda is the one who talked about the twin cable idea on the new Honda slides. He also observed that too many people get all worked up about their carburetor and start adjusting on it before they even take the trouble to find out whether they're

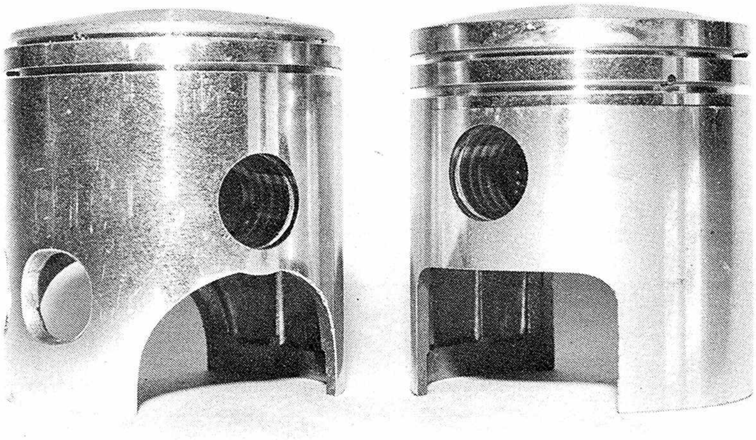
1) Size of cut away can be influenced by altitude at which run is made. Smallest cut offers richest low-speed running. Conversely, largest=leanest.

2) No, this isn't a Harley idle jet! It's a shot through a typical two-stroke cylinder for a look at interesting intake, exhaust and transfer ports.

3) Four drawings show stage-by-stage acceleration cycle of slide-type carb. Principals of function are same, though details vary from brand to brand.

4) Shape and amount of piston cut away in two-strokes is critical to performance and can influence distribution of torque over entire power cycle.

5) Here we see a pair of two-stroke cylinders from the outside. Reed intake port at left, exhaust on right. Pistons don't normally come this high.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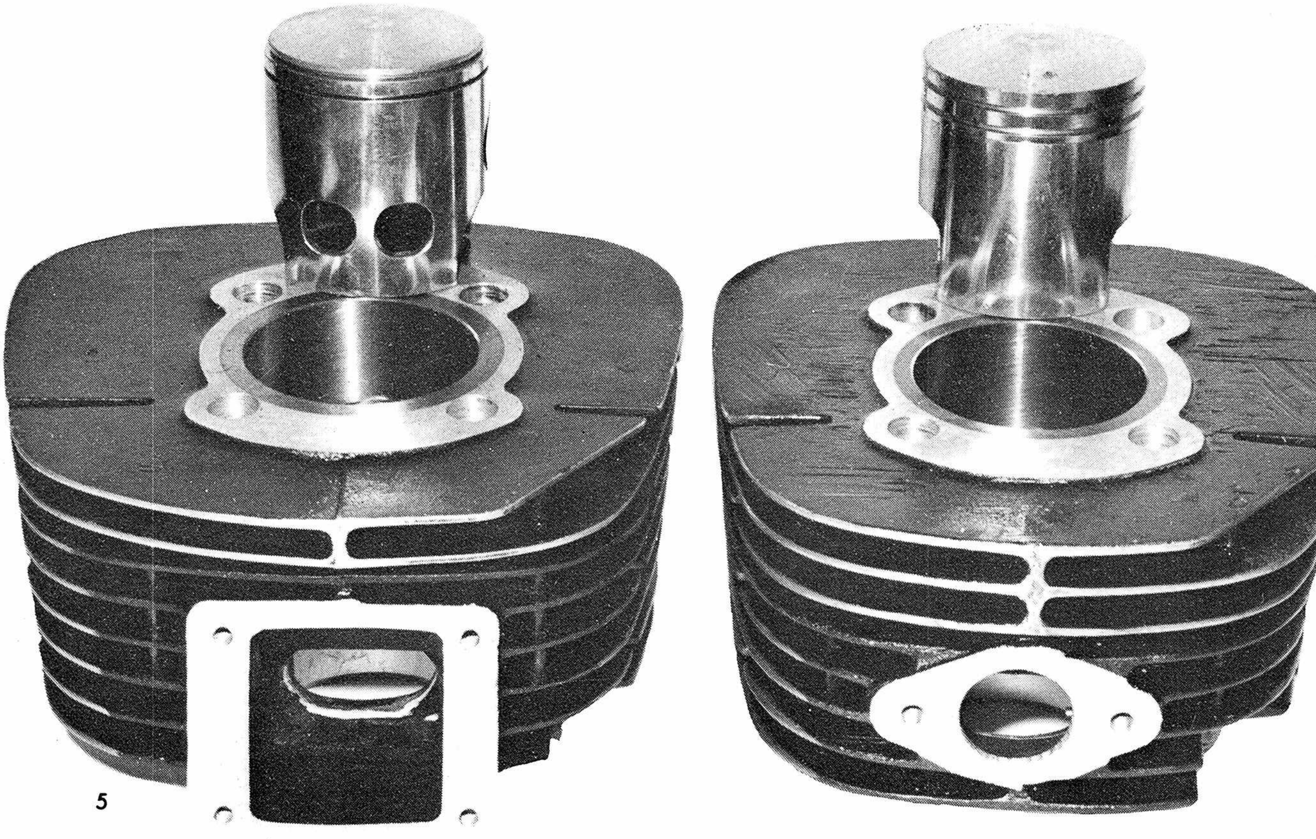
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getting an ample fuel supply from the tank. A darned good suggestion! I've seen people push their bike several blocks into my shop so I could take a broom straw and open up the vent hole in their gas cap. They also have been known to fail to check the balance tube between twin carburetors before deciding they need a tune up.

Tom Patton at Bultaco brought up the matter of plug reading when tuning carburetors. There's a tendency to take readings after putting around on the street which, in fact, gives little indication of running condition. If it's the main jet you're testing then it'll have to be done after a freeway-type main jet run. The reading should be taken immediately, not after you've left the freeway and rolled into your garage. An off-white, parched appearance will show you that combustion is involving too much air, go richer. To the opposite, a black, sooty plug will indicate the need to try something a bit leaner. It's that dry, brown look you're after. George Wall of Hercules, with whom I discussed the Bing carburetors, said he noticed that most home tuners tend to back adjustment screws out too far. On that subject, there's always a manual recommendation for just how far to back out that adjustment screw and remember, as I mentioned earlier in this discussion, always tune stage-by-stage, starting at idle and working up. Jim Wismer, one of the Harley-David-

1) Paired reed valve intake system is exemplary of sophisticated air-fuel intake system on current Yamaha competition two-strokers.

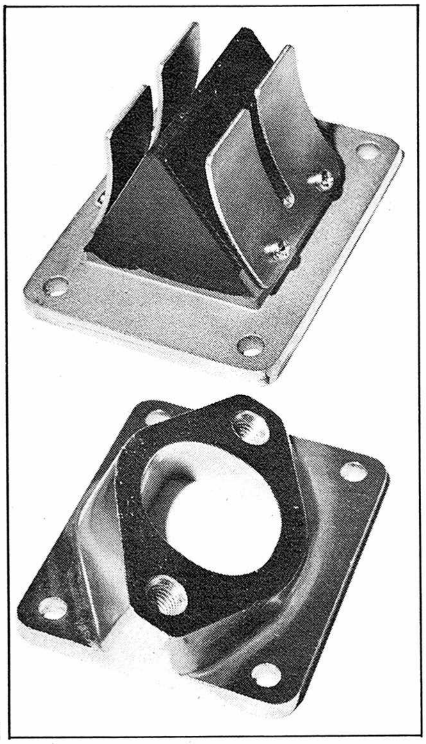
2) Here reed valve pair sets pose next to massive intake port. Flexible "flappers" open and close with eng-impulses. Can be replaced if worn.

3) A head-on look at Yamaha reed valve pairs as cylinder, with intake port opening, occupies foreground. Port polishing would help performance.

4) Another type of reed valve assembly is shown along with full manifold and gasket assembly. Reed action pulses work well with pumper carb.

5) Reeds and reed mount are removed from manifold as if to inspect. Reed petals should be examined periodically for signs of fatigue, chipping.

6) Custom reeds are available for replacements. Fiber-epoxy type offered by D-H Enterprises is "digestible."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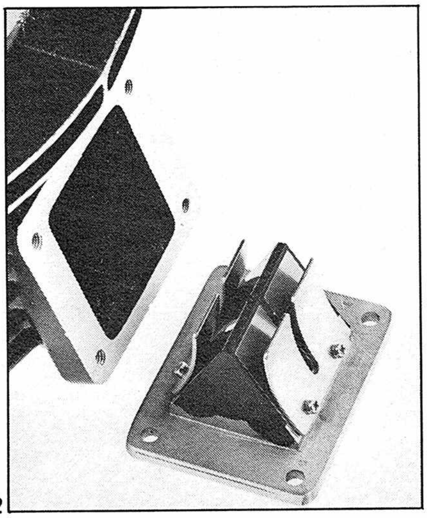
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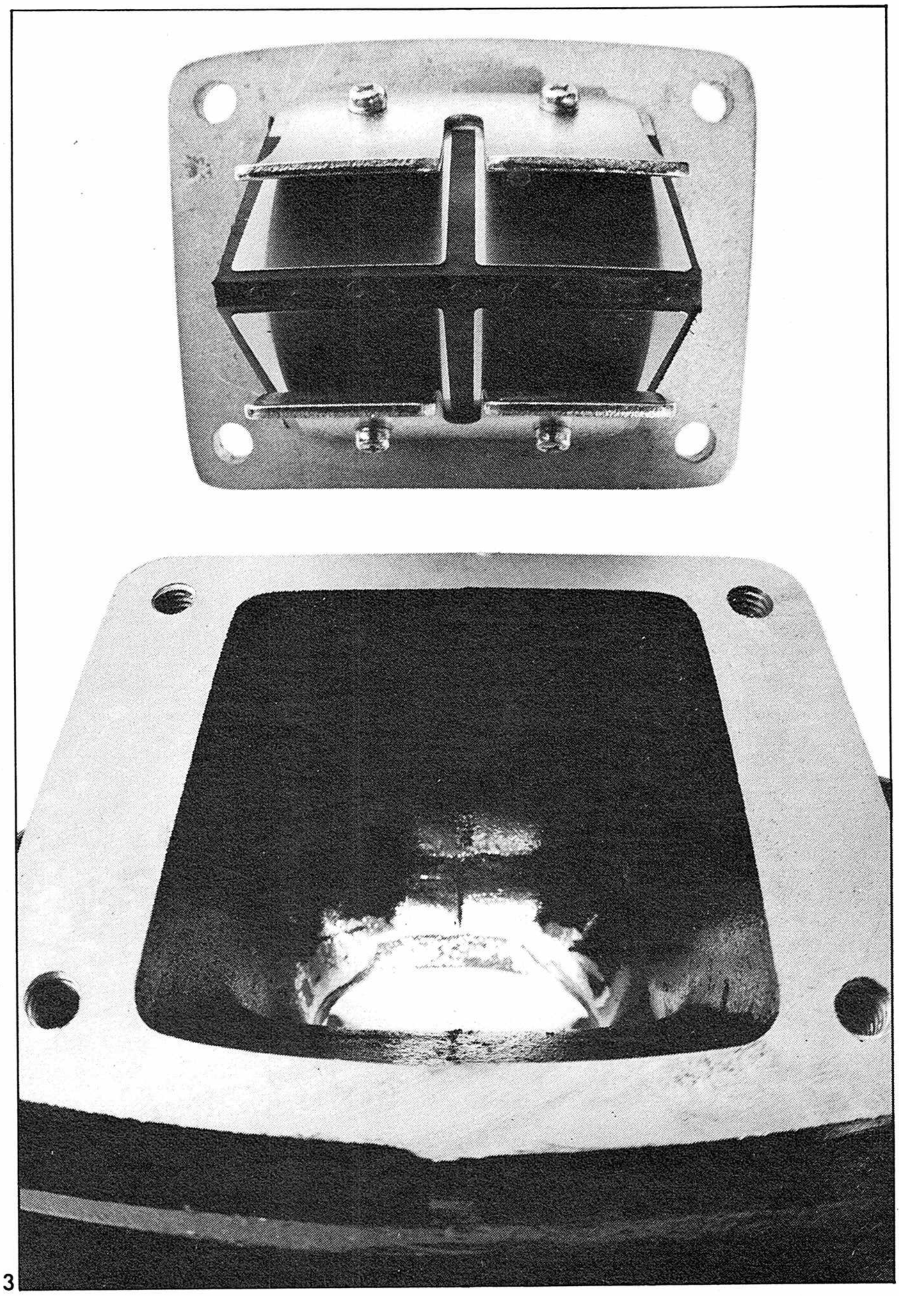
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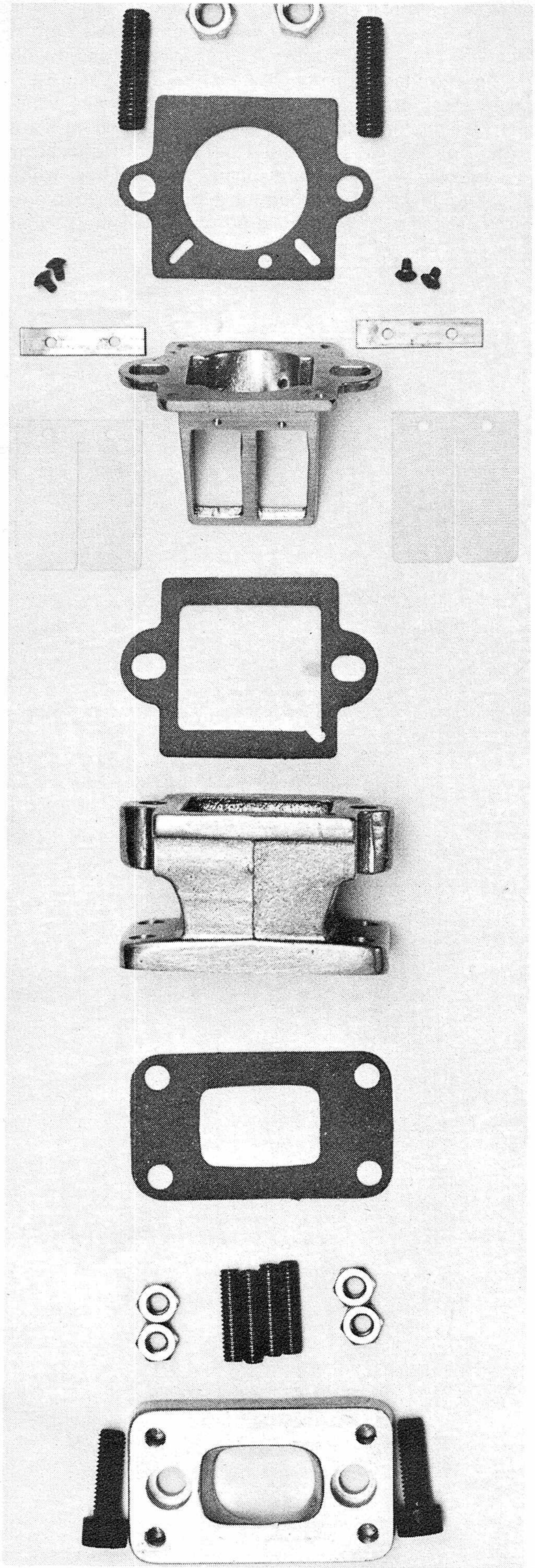

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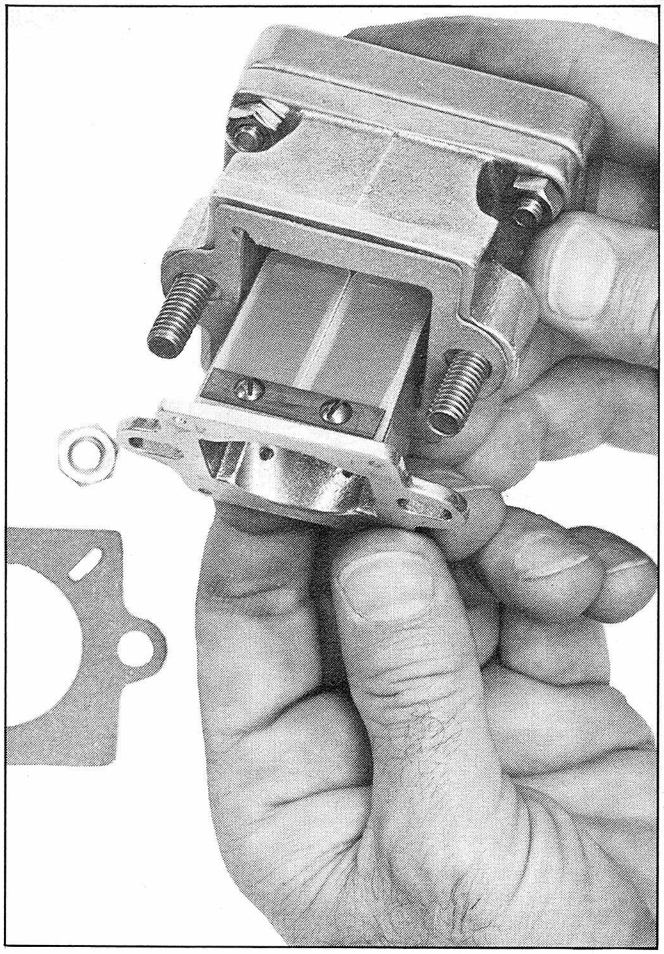

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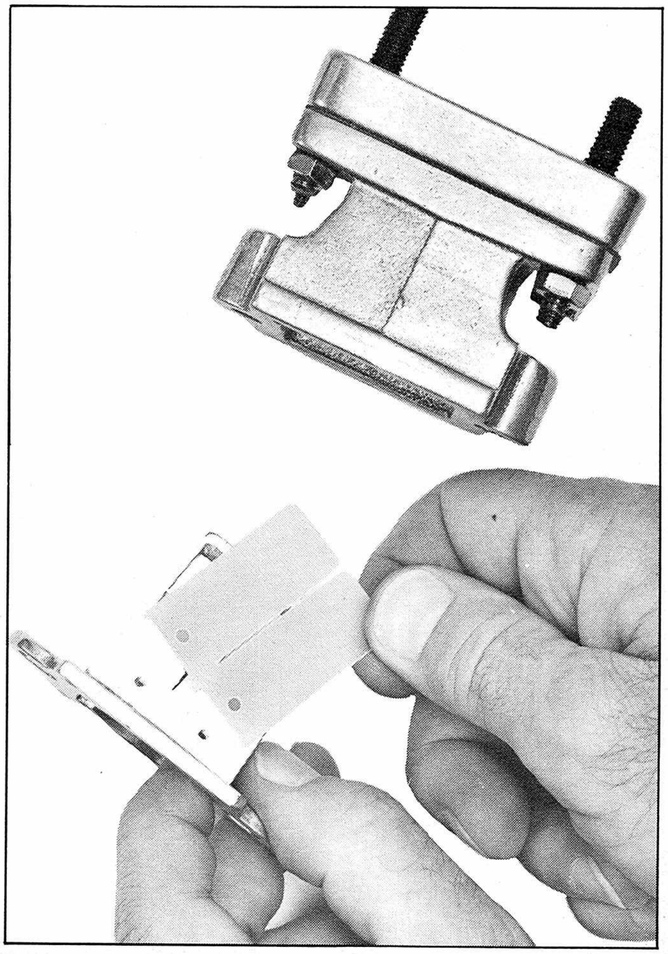

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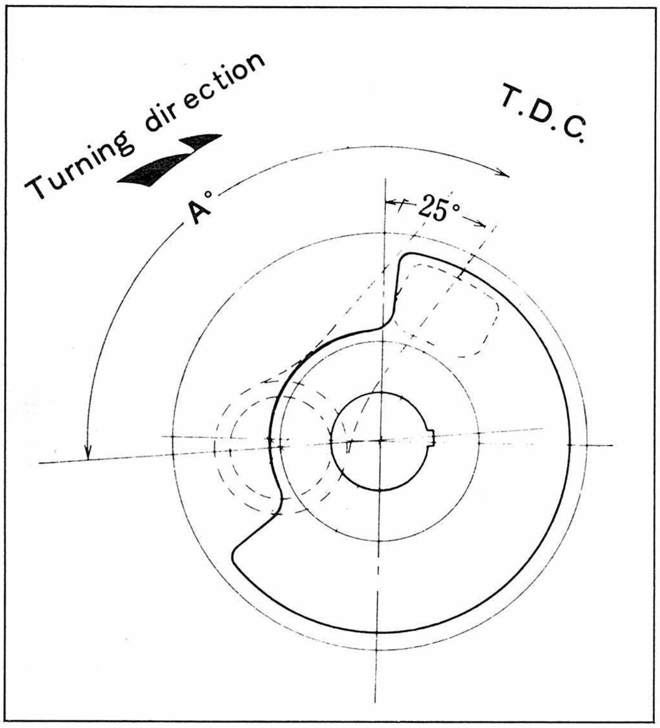
CARBURETORS

son people I conacted locally, aptly pointed to the fact that even something as simple and inexpensive as the addition of a velocity stack helps. If, however, you've removed an air filter in order to add the stack, bear in mind that you may very well be running somewhat leaner than before and that re-adjustment of the carburetor probably will be necessary. On the subject of air cleaners, I have never found reason to believe that they are absolutely necessary on street bikes. In fact, Jerry Fairchild, a prominent builder and tuner of Class "A" speedway machines for over 40 years, will tell you with great conviction that an air cleaner isn't even necessary on a dirt tracker. To prove his point he has for many years run his Prestwich and Jawa engines with naught but a funnel and screen ". . . to keep out the big chunks." Fuel filtration is another proposition: It's a good idea because dirt and stray flakes of paint can raise hob inside a carburetor. A trick I've used to prevent build-up of rust on the bottom



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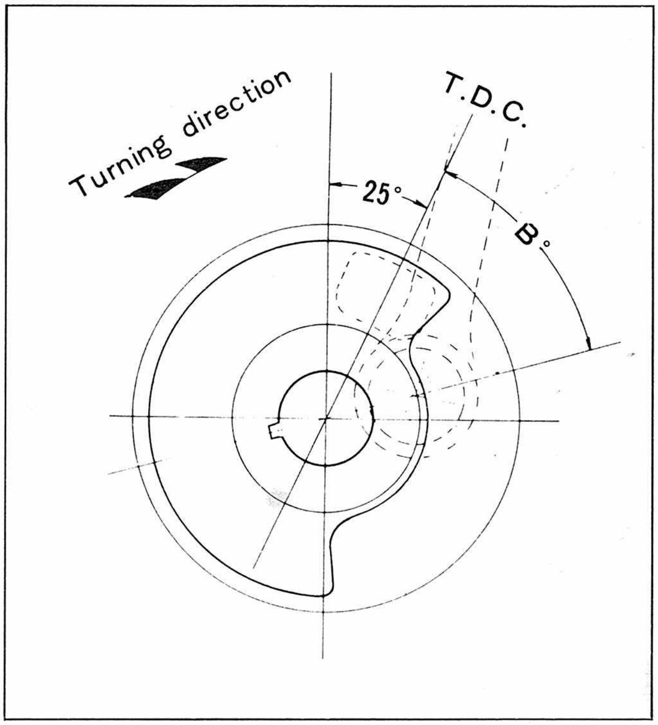

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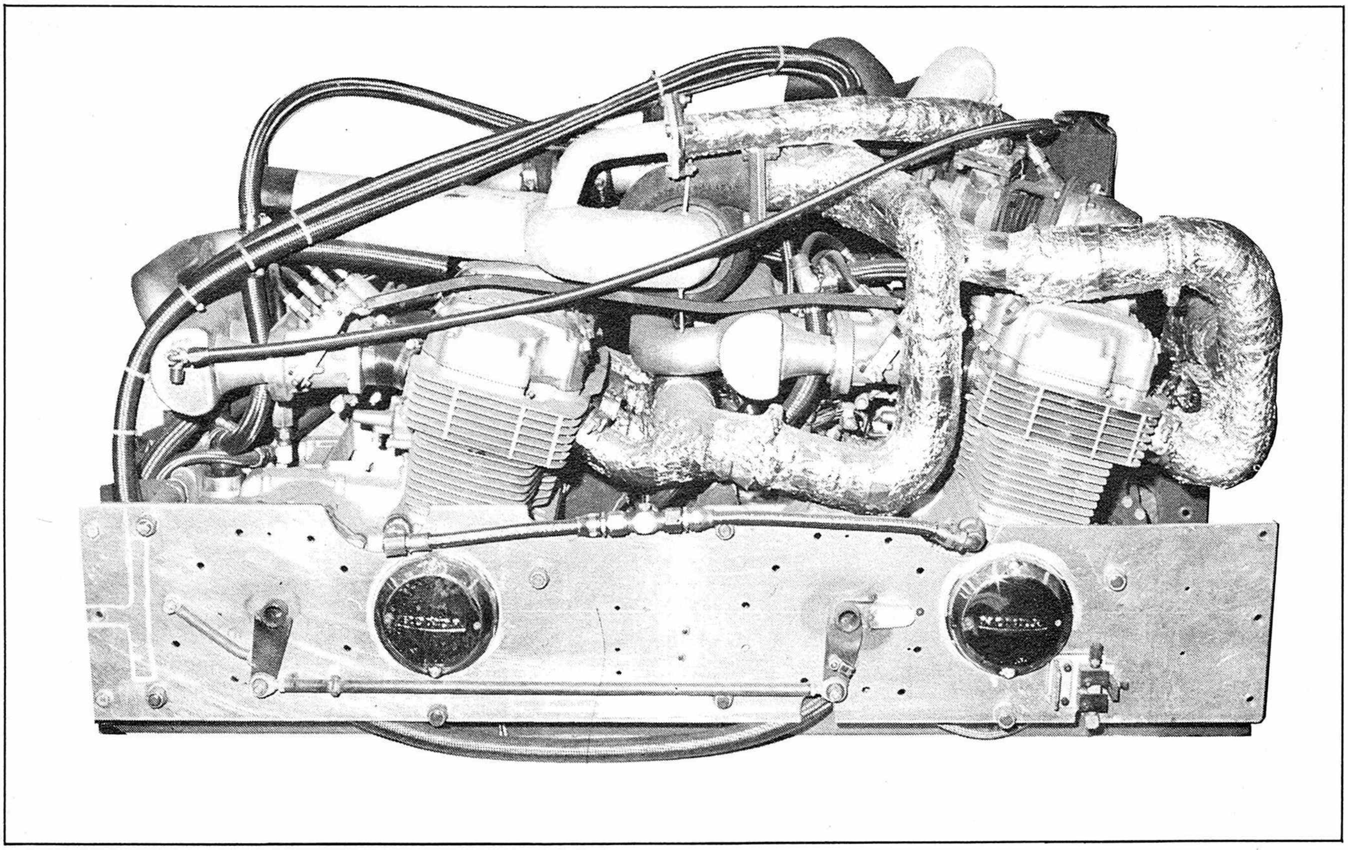
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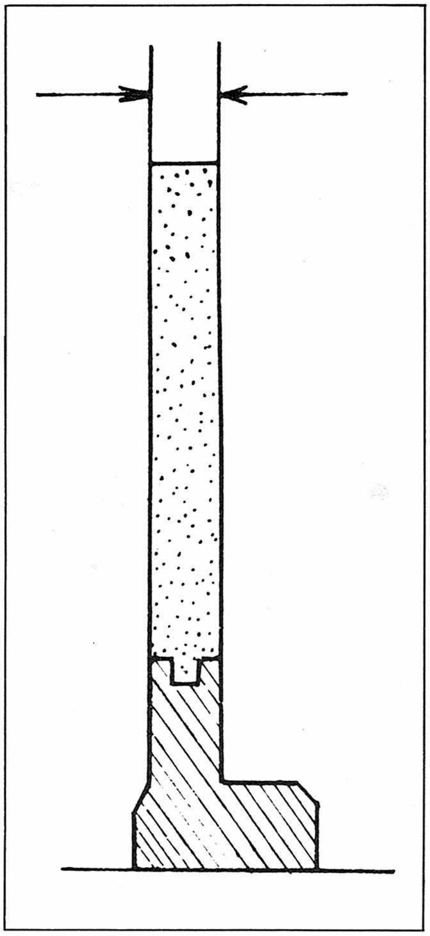
of a gas tank involves dropping in a couple of "00" buckshot. They're too big (about ⅓-inch) to become stuck in the petcock and won't rust. They roll around inside enough to prevent rust deposits without making enough noise to become an annoyance. Finally, don't be caught up in the popular misbelief that installing a set of megaphones on a bike calls for rejetting the carburetor(s). The idea going around is that megaphones will "open up" the exhaust system and cause substantially leaner running. Maybe so with completely open, true racing megs, but with anti-noise laws being what they are, the truth is that megaphones have become just as restrictive to exhaust systems as original equipment factory mufflers. In fact, a lot of today's megaphones are even more restrictive than factory equipment! No longer megaphones, most have become inefficient and unnecessarily restrictive mufflers with a sporty exterior. Their use will nearly always cost you a couple of ponies. But, like I said, looking fast is half the fun!

4



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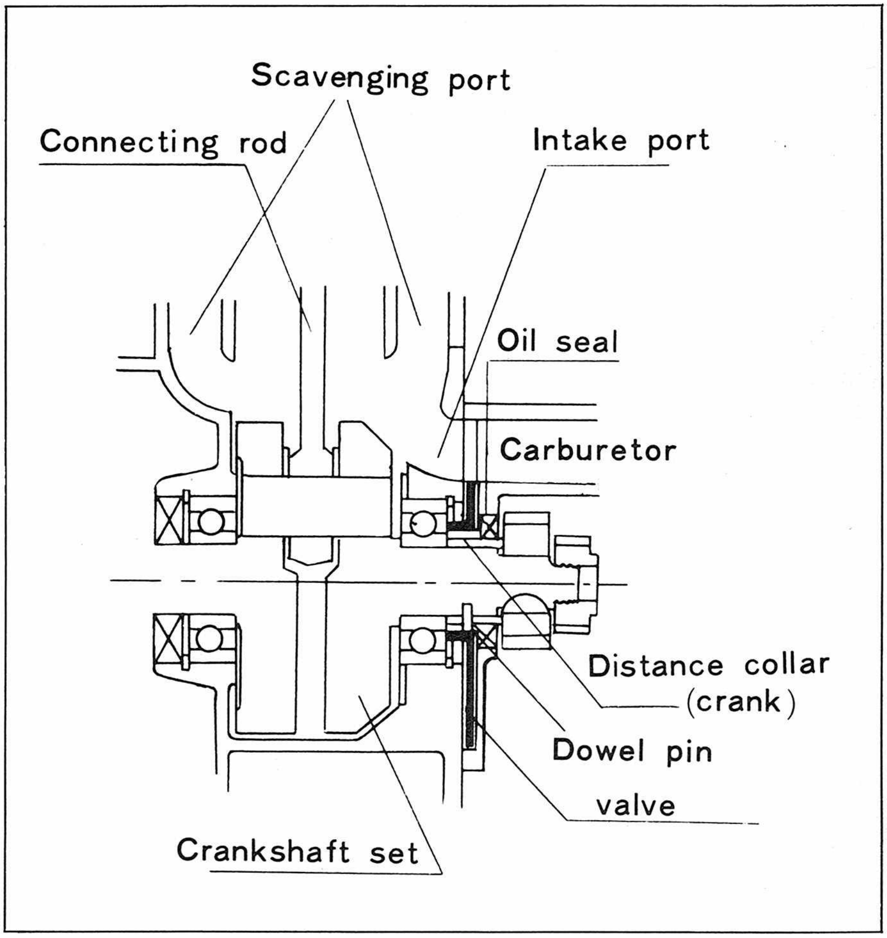

1) Rotary valve provides timing for admission of air-fuel mix in 2-stroke engines. Here, valve is about to open port to accept air-fuel mix from carb.

2) Intake cycle completed, rotary valve has again covered intake port, readying engine for combustion cycle. Note position of con rod and port.

3) Hilborn injection and Air Research supercharging combined on Honda's exotic 8-cylinder record attempting Hawk. Note air collectors for carbs.

4) Cross-sectioned rotary valve is drawn to show importance of maintaining correct thickness, a condition which should be checked periodically.

5) Bowels of rotary-valve 2-stroke engine shown in blackline detail to indicate relationship between carburetor, intake port and scavenging port system.

6) Snail cage housing for turbocharger holds exhaust driven impeller claimed to turn up to 30,000 rpm. Power loss to drive virtually nil.

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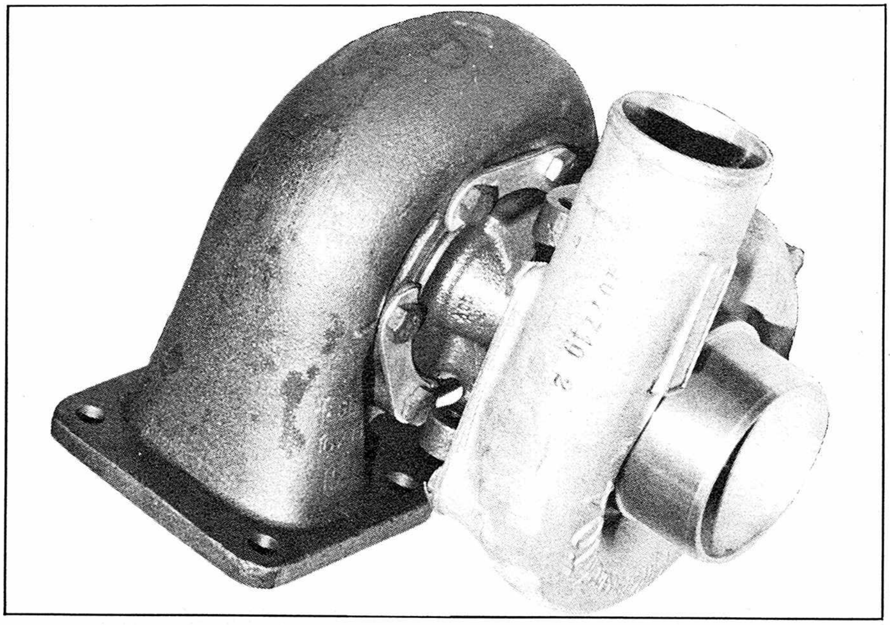
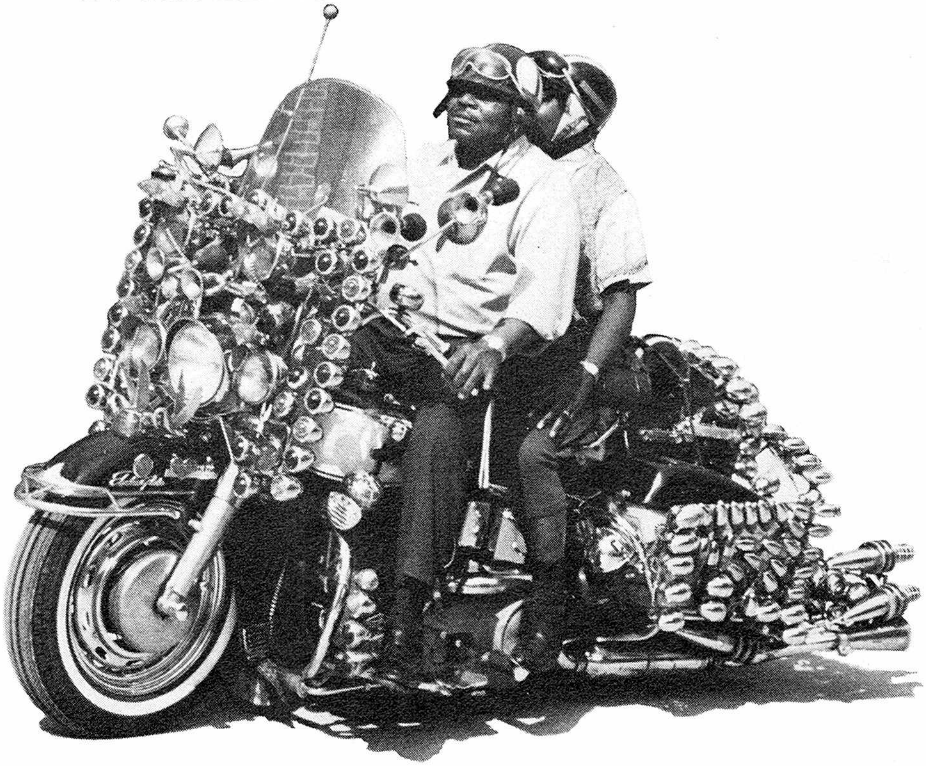


ELECTRICAL SYSTEMS

An understanding of how the juice flows is important to solving trouble-shooting problems. Digest this chapter—it isn't as difficult as you may think.

BY JIM LEWIS

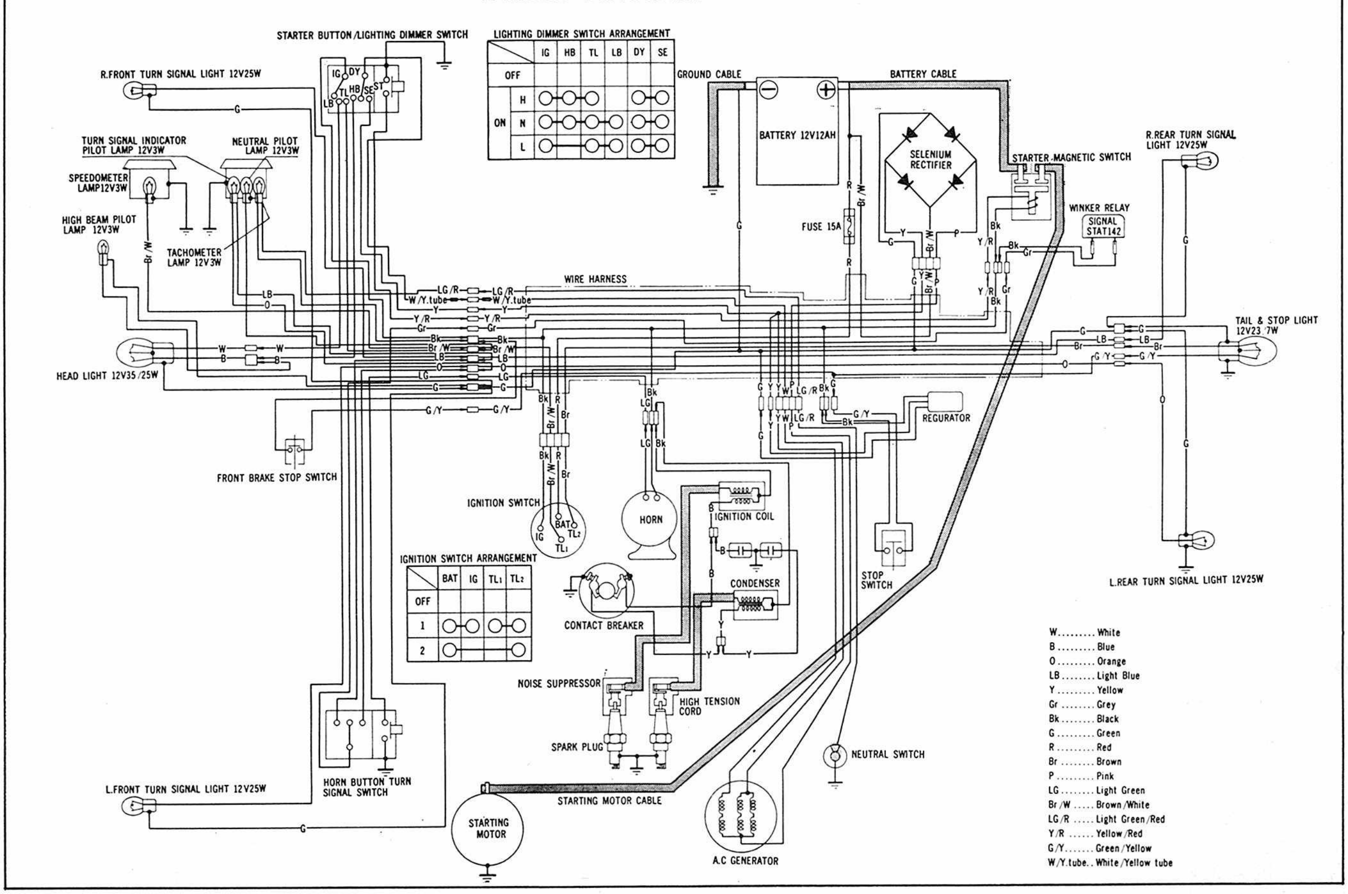


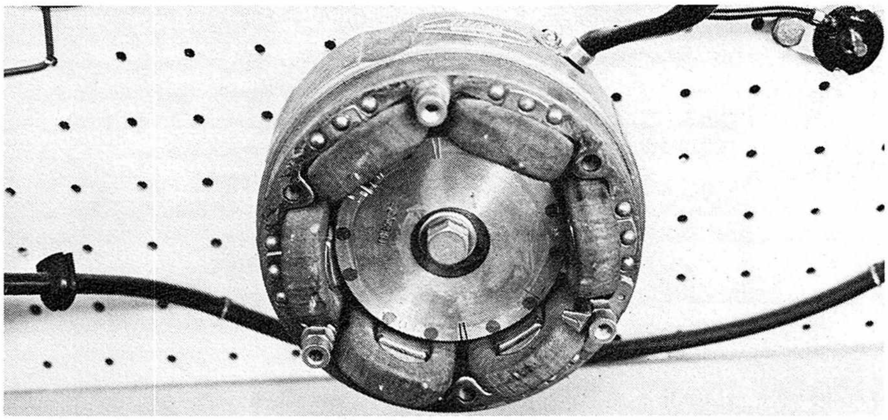
What's the matter, boobie? You say that electricity has you thoroughly confused? You say that the closest you want to come to the electrical system on your motorcycle is when the spark plug needs changing? And that even then, you get zapped by the spark?

Well, cheer up old buddy. It can be explained to the layman in terms and concepts that even the rankest novice mechanic can comprehend. The biggest problem with most explanations is the terminology, the big, unfamiliar words that the electronics-types throw around with total abandon. Most people have a vague idea what volts are and know that amps have something to do with it too. But those words are no longer in popular usage any more. Now it's impedance, electrical potential difference and electromotive force.

Many who try to obtain a better understanding of electricity, become

WIRING DIAGRAM





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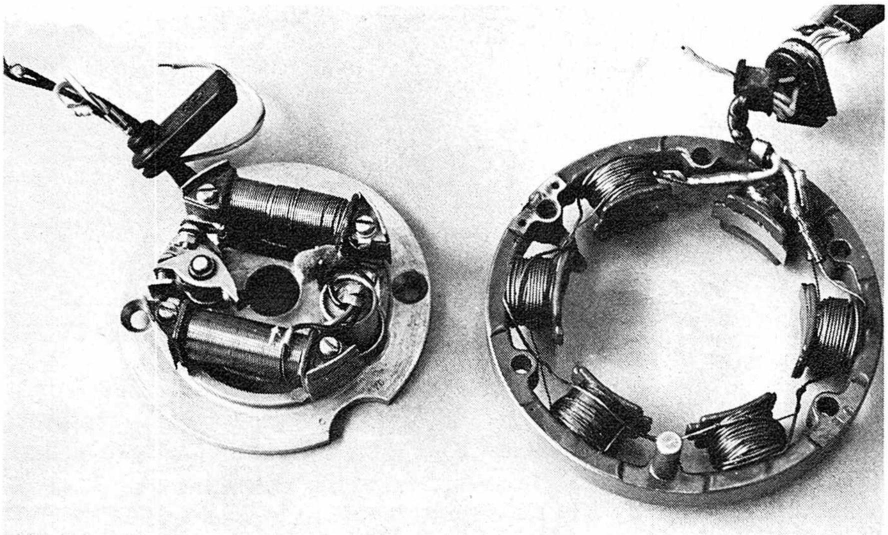

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so tied up with the unfamiliar words in explanations, articles and textbooks that they soon give it up as a lost cause. Here then, is your chance to take a grasp on the subject without those problems because the whole thing will be dealt with using an absolute minimum of technical words. If you should wish, once you have an idea of what is going on inside those little copper wires, then you can pick up a book at the library and learn the fancy names.

ELECTRICS THEORY

A favorite way to explain electricity is to substitute water for electrons inside the wires. That's a little hard for most of us to sink into our confused skulls, so let's forget about the wires and substitute a complete water system, pipes and all.

We have a water tank up on a hill with water, a means of piping it down to the bottom of the hill and a way of connecting hoses up to faucets at the bottom. We can fasten a number of garden hoses to the valves and lead them just about anywhere we want and do quite a few things with the water. Put a small nozzle on another and squirt a high stream of water with that one. Use another one to fill a water bed and another to operate the sluice in a gold mining operation.

There are hundreds more things that might be done with more hoses from this tank except that there is a limit to the number of hoses that this particular system can support. That means that we can't have too many connected to it. There's also the fact that the tank would be emptied very quickly if we ran a large number of hoses from it.

Now we have a system of water up in a tank, a pipe that allows us to use it but we know that there's a limit to how much we can draw from it. Let's take one of those hoses and run it over to a boiler. We fill it up and light off the boiler. Steam is produced and we add just a bit more water to keep the level up from time to time. The steam drives a paddle wheel which we connect to a water pump down by the lake. The pump feeds water into a pipe that goes up to the tank on top of the hill. Notice, though, that the force of the water coming out of the hose at the boiler doesn't provide the energy directly to refill the tank. Water is used along with another form of energy (fire and resultant heat) to do that job.

When everything is going right, that's the principle behind most electrical systems on a motorcycle. The battery (water tank) is charged (set up on a hill and filled) and it then supplies electricity (water) for various jobs and is itself replenished by a generator (water pump).

Now that wasn't too bad was it? Impedance, EMF and potential difference weren't mentioned once. Admittedly, it was a very simple-minded explanation and has some drawbacks, but it's a start in the right direction for most beginners. From here, let's move on and talk a bit about electric generators and how they work.

Electricity can be produced a number of different ways. You've probably walked across a wool rug in your socks and then received a shock when you touched a doorknob. It's not likely that you fully realized it at the time, but you were an electric generator and a battery all at the same time. Your socks picked up a small electric charge by rubbing across the rug and it was stored in your body. The entire charge of electricity was released when you touched a metal object. This is plain old "static" electricity, the same stuff that Benjamin Franklin played around with in 1746. It doesn't have much value today for anything except thunder and lightning because it is used up instantly. To be useful, it must be continuous and steady.

Static electricity is made by rubbing two different materials together like silk socks and wool or cat's fur and a rubber rod. There's another more efficient way to make electricity and that's with a magnet and a coil of wire. When a conductor is moved through a magnetic field, an electromotive force or EMF is induced in it. If the conductor forms a loop or closed circuit, an electric current will register on a sensitive meter connected in the conductor circuit. When the conductor is moved downwards, the needle swings in a direction corresponding

1. Typical A.C. generator with magnets mounted inside the solid wheel in center. Coils of wire are situated around the circle and connected together for added voltage output.

2. Generator coils can be mounted in such a way that the magnets either rotate around the coils on the outside or rotate around inside the circle.

to the direction of current flow. If the conductor is moved upwards, the needle will swing in the opposite direction, indicating that the current flow is also in the opposite direction.

The amount of movement of the needle will depend upon the speed at which the conductor is moved up and down, and the density of the magnetic field. The same effect can be obtained by moving the magnet in and out of the coil of wire. Induction will again take place and current flows in the wire coil. This time, because the coil consists of several turns of wire, instead of one, the induction will be increased, thereby giving a greater output. The meter will register in exactly the same manner as before, only in with a greater deflection.

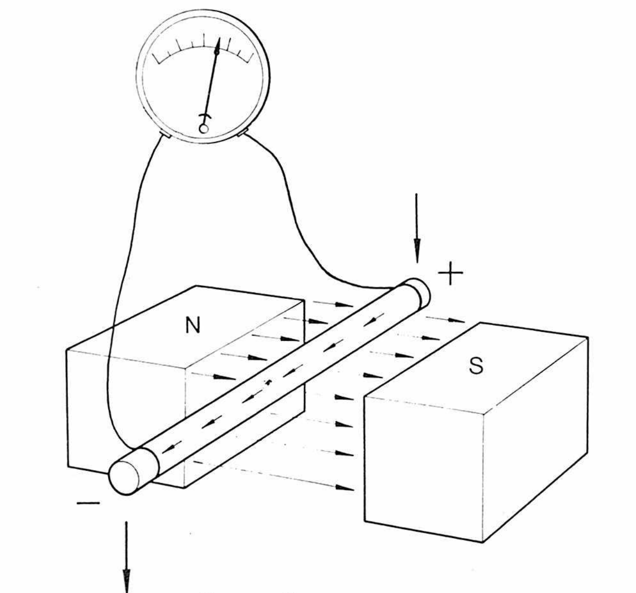
When the coil has been wound round an iron yoke, which concentrated the magnetic field around the wire coil, we have a simple alternator. In the center of the yoke a bar magnet is rotated.

The direction of the magnetic field will change every 180 degrees of rotation of the magnet. The north pole is at the top, but after the magnet has rotated 180 degrees, the south pole is at the top. The direction of current flow in the coil has been reversed. Induction has taken place due to movement of the magnet and alternating current has been produced.

The sine wave shown is a simple representation of the current output from an elementary alternator. It shows the current during one complete revolution of the bar magnet alternator.

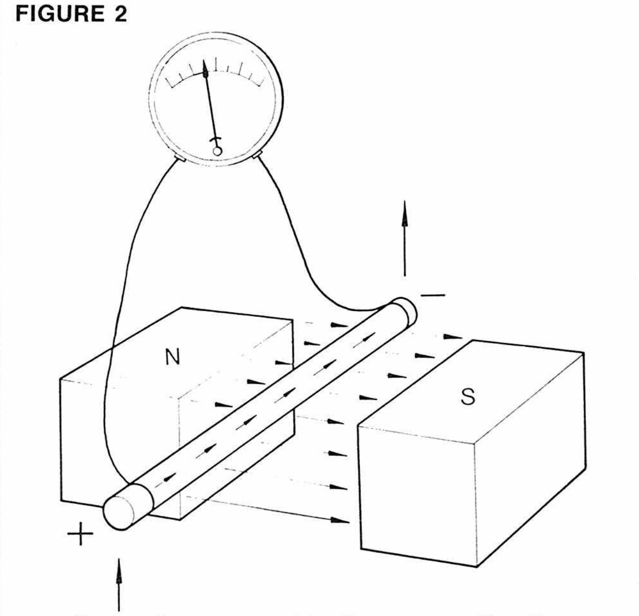
The vertical line represents the current in amperes, which is positive—above the neutral point or horizontal line; and negative below the neutral line. Starting from the left side, this line is divided into 360 degrees, that is, one complete revolution of the bar magnet. From zero degrees the current gradually builds up to its maximum value at 90 degrees; then

FIGURE 1



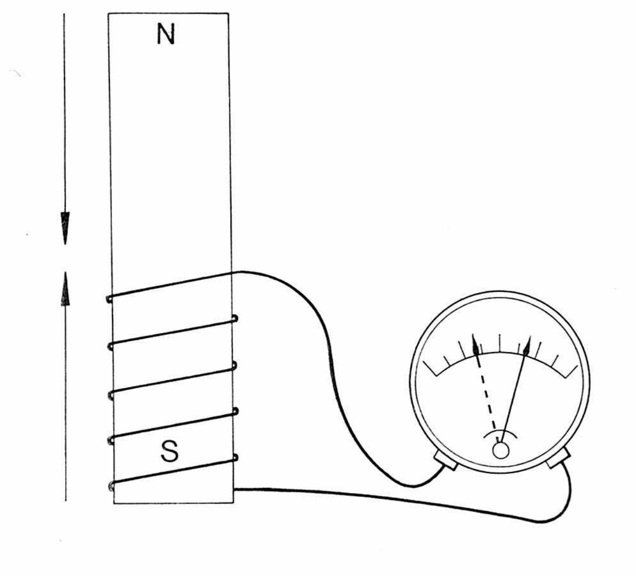
Generating a current

FIGURE 2



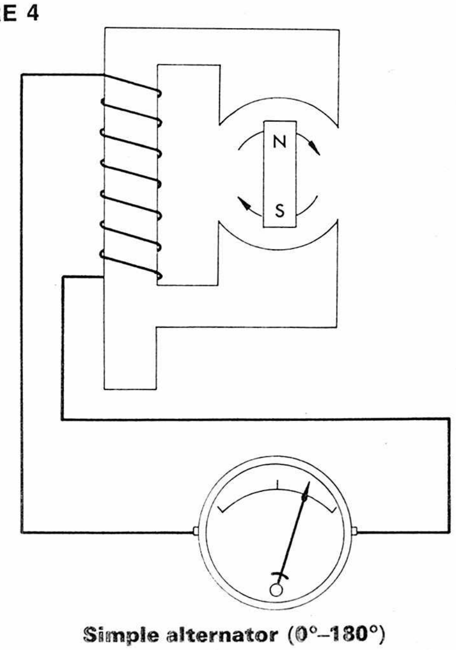
Generating a current in the reverse direction

FIGURE 3



Moving the magnet inside the conductor

FIGURE 4



Simple alternator (0°–180°)

gradually decreases until it is zero again at 180 degrees, becoming zero again at 360. This cycle is repeated as long as the magnet is rotated.

Alternating current of this type is of limited use. A battery cannot be connected directly to an alternator for charging purposes. A battery can only be charged by DC current. There are two ways of converting AC current into DC: By means of a mechanical switching device and through a solid state rectifier.

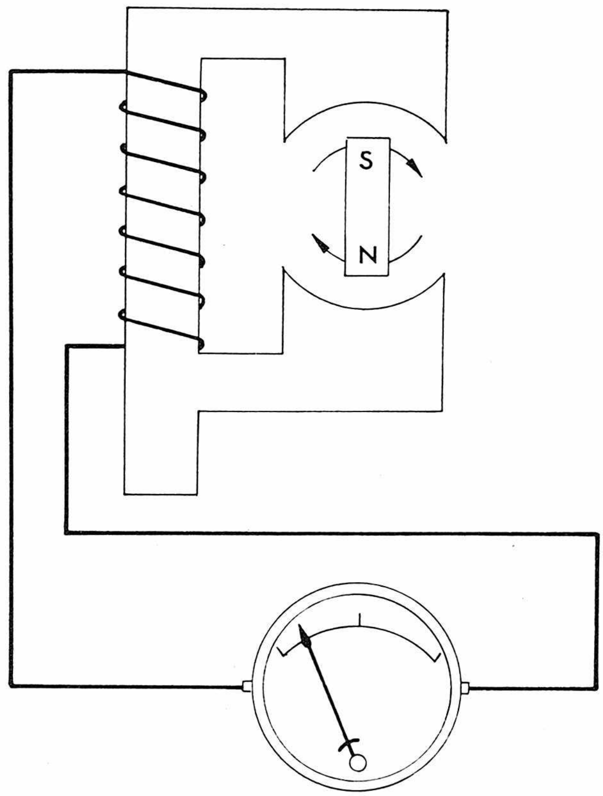
DC generators consist of an alternator and the mechanical switching device made up of a commutator and graphite brushes. When the alternator is in the zero to 180 degree phase, the switch is in one position that allows the current to pass through the loop. As the alternator rotates to the 180 to 360 degree phase, the commutator and brushes switch the leads so that they are reversed. This negates the backward flow of current with the result that the current in the loop beyond the switch flows only in one direction as evidenced by the meter which deflects only to one side. In other words, the current is DC.

Wear in the brushes and commutator is the chief disadvantage with this system. In an effort to keep this problem minimal, the brushes, which are the easiest to replace, are made of soft graphite, much the same as is used in a lead pencil. Eventually though, even the brass commutator will need servicing and cleaning.

With the advent of solid-state rectifiers, converting AC to DC was very much simplified. Consisting of four diodes which allow current to pass only in one direction, the rectifier does the job of the brushes and commutator without any moving or rubbing parts to wear out. By proper arrangement of the diodes inside the rectifier, AC current coming into the rectifier is converted to DC.

Motorcycles aren't very complicated as compared to a television or a stereo. Lights and turn signals can run straight off the battery and generator. Ignition, however, does need special attention. The 12 volts common to most of the motorcycle systems isn't capable of jumping the .025-inch gap in the spark plug electrodes. Just 12 volts aren't enough power in that form. Just as water will squirt farther when the stream is made smaller through a nozzle, so will electricity "squirt" farther if its form is altered. The battery's 12 volts is changed into about 20,000 volts. The total volume of electricity is the same as before but it will now jump the spark plug gap and ignite the gas/air mixture inside the engine.

FIGURE 5



Converting the 12 volts into 20,000 volts is the job of the high tension coil and it works on the same principle as a generator. A coil of wire sits in a magnetic field that is changing in strength. The magnet, in this case, is an electromagnet which is very handy for this type of a job. It can be turned on and turned off with the result that the magnetic field strength changes without any moving parts. An ignition coil has hundreds and hundreds of loops of very thin wire. This configuration will produce a very high voltage but not much current or volume. (Actually, a greater volume would be preferred, but that would require a larger source of electricity, more than what a convenient-size battery can provide.)

Hook a spark plug up to the coil of very thin wire, connect a 12 volt battery to the electromagnet and then take a look at the spark plug. No spark is visible. Why? Because the magnetic field has to be *changing* to produce electricity and that 12 volts of DC electricity makes a rock-steady magnetic field around the coil.

The easiest way to change this magnetic field is to simply shut if off. From one instant to the next, the magnetic field disappears. The coil of very thin wire reacts to this change and instantly electricity is induced inside its wire. The 20,000 volts charge down to the spark plug and zap across the gap. Simple and very effective.

If you had been watching when you first hooked up the battery (and if the battery had been a big heavy-duty model) you might have seen a spark at the plug. The sudden appearance of a magnetic field is also a change and that would produce 20,000 volts in the second coil just as the disappearance did when it was shut off. But most motorcycles have small batteries and they aren't capable of creating the magnetic field suddenly enough for the thin wire coil to do its thing. Simply shutting it off is always a sudden occurrence and most bikes operate on that principle.

The electric switch that shuts off the battery's 12 volts to the electromagnet and causes the collapse of the magnetic field is the contact breaker point. When the points are closed or together, the 12 volts flow through the electromagnet. It is a steady magnetic field and nothing is produced in the thin wire coil. As the points open, the

12 volts are shut off, the magnetic field disappears and the coil reacts to produce the 20,000 for the plug.

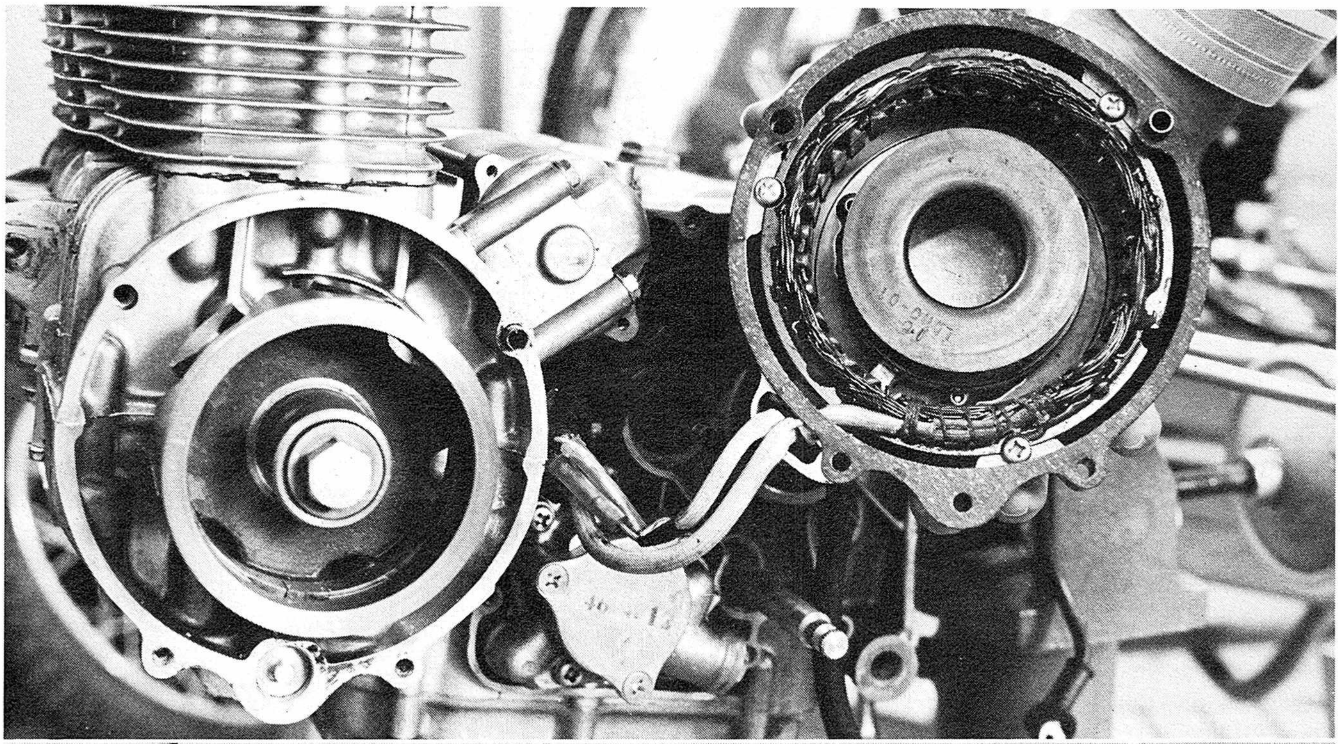
That's basically how it works. If you want to know more of the details, you might pick up some books on basic electricity at the library.

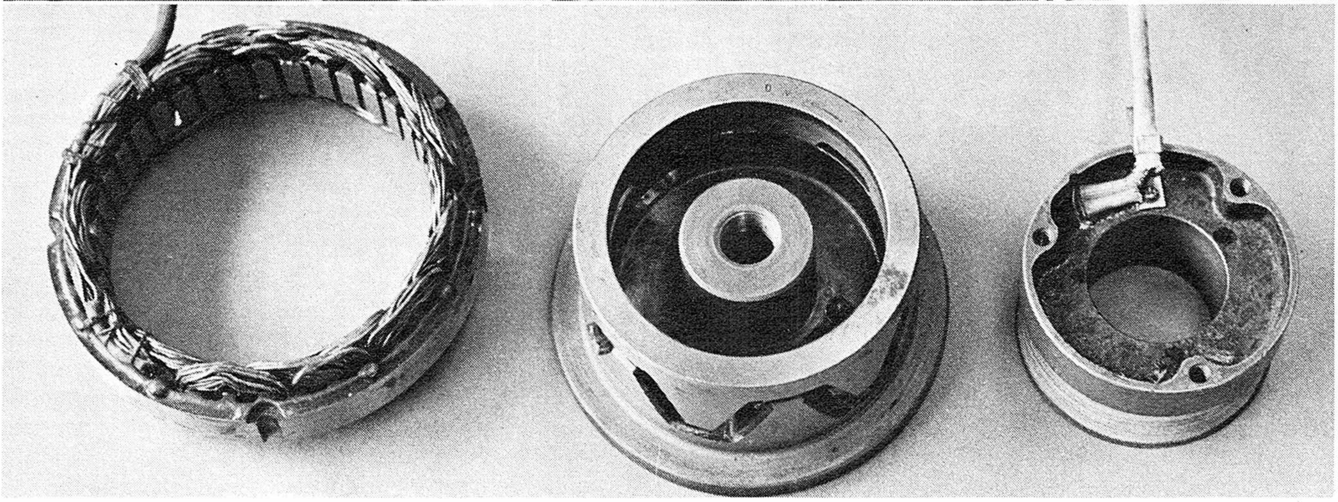
DC BATTERY COILS

The majority of the motorcycles sold today are of the battery-coil operation. A wet-cell battery under the seat provides the operating current for the entire system, lights and ignition. It provides steady electricity at all times as long as it's in good shape and has a full charge. A battery converts electrical energy into chemical energy which is stored in the lead plates and the acid inside the plastic case. In a fully charged, fresh battery, this acid (called electrolyte) is a solution of about 38 percent sulfuric acid. When the switch is turned on, electrons flow from the negative plates in the battery to the positive plates to provide the electricity. Eventually, the supply of electrons are depleted and the battery is no longer fully charged. Charging it replenishes the supply of electrons for later use. Test for a full charge with a hydrometer which will measure the specific gravity of the acid. It should be about 1.29 when fully recharged. This will be enough to activate the ignition coil which will produce a hot spark for easy starting. Lights will be even and bright at all engine speeds, including idle. Until fairly recently, most motorcycles manufacturers used DC generators to support the battery and keep it fully charged. On paper, this sounds simple and easy but, as you can guess, things never work out that well in reality. Motorcycle electrical systems have a problem: The generator produces too much most of the time. The problem isn't solved by using a smaller generator, because it wouldn't be able to keep up with the electrical demands when lights are in use at night.

The answer was to incorporate a voltage regulator. Excessive voltage is either prevented or bled off before it flows to the battery. If it were allowed to pass into the battery unchecked, the battery would soon overheat and deteriorate. This was the problem with some of the British motorcycles in the mid-1960s and the reason they needed battery replacement every 12 months or so.

The principle behind the older DC generator voltage regulators was to bleed off some of the voltage through





a resistor. This cut down on the amount of current that passed through to the battery and helped prevent damage.

The resistor was switched into the circuit by an electromagnetic switch which was controlled by the battery. As long as the battery was up to nearly full strength, it could hold the electromagnetic switch on and this would cause the resistor to act on the generator and bleed off some of the electricity. The battery was already fully charged and didn't need the generator's full output.

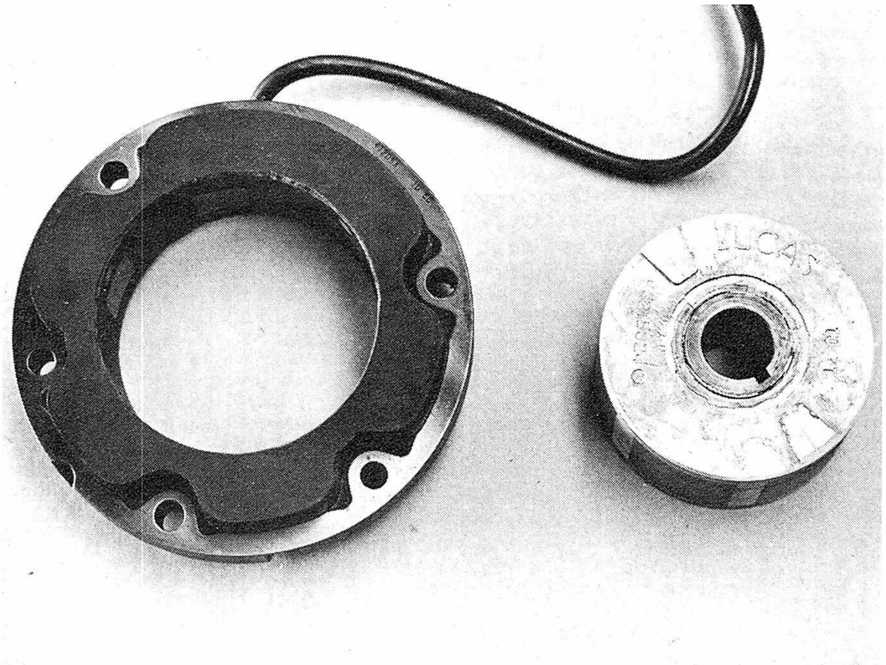
These older style regulators work very much like an automotive regulator and are very difficult to adjust without exact specifications and without any meters. If you believe that yours isn't doing its job, first check the surfaces of the switch points. These resemble contact breaker points and they can become corroded. If this happens, the resistor may not be brought into the circuit even though the electromagnetic switch is closing the points. Very, very gently, dress the point faces up with a clean point file or with a narrow strip of #200 wet-or-dry sandpaper. Be careful not to warp or bend the thin metal arms that the point surfaces are mounted on. If this does no good, check for broken wires or leads and only replace the regulator as a last resort.

DC generators have not been used extensively for quite some time. Triumph used them on their twins up until the late 1950s and Harley-Davidson dropped them a couple years ago in favor of the AC generator. Yamaha still uses a DC generator on their 125 Enduro model. The reason for this is that the generator doubles as a starter motor. It is relatively easy to convert any DC generator over to a motor by changing a couple of wires around. Pressing the starter button feeds the battery's current into the proper wires to cause the generator to act like a motor. After the engine is running and the starter button is released, the generator operates in the normal manner and supplies current again to the battery.

The biggest drawback to a DC generator is the commutator and brushes. Generally, anytime a DC generator quits, it is because of the brushes and, occasionally, the commutator. But replacing the brushes is fairly simple. They are held in place by a coil-shaped spring which can be lifted out of the way. The brushes, which are made of graphite; are then free to be removed from their guide slot. Disconnect the wire lead and completely remove the lead and brush from the generator. Slip a new brush into the guide slot, connect the wire lead and set the coil spring into place.

After a long period of operation, it may be necessary to have the commutator renewed. This involves cleaning the grooves between the faces and sometimes smoothing the faces and making them true again. If they are left rough, the brushes will wear out rapidly.

Once past the battery in the system, lights, switches and ignition are usually straightforward. There is little difference in most battery systems other than generator and regulator



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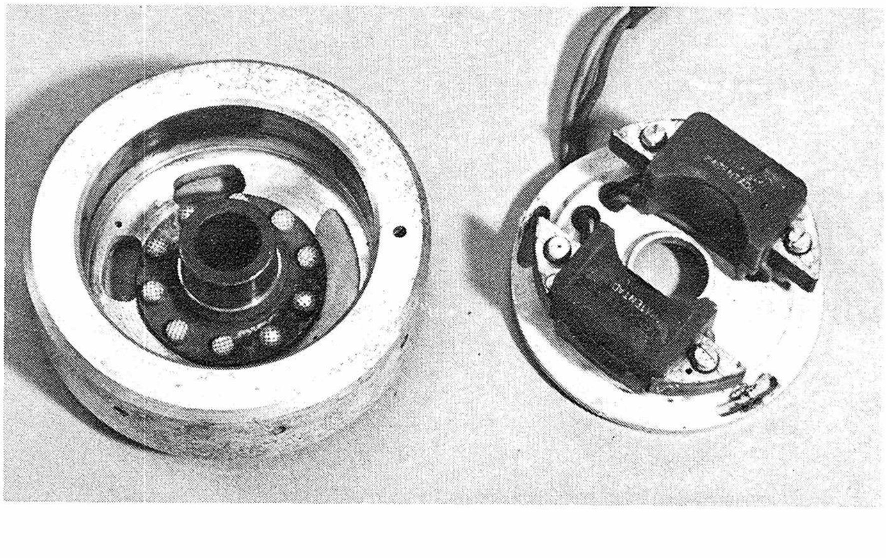

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1. Newer Hondas are using a variation on the A.C. generator. Instead of permanent magnets to create the field, electromagnets are employed. Battery supplies current to activate them and the field is constant due to D.C. mode. Since the electromagnets are stationary, the magnetic field must be changed somehow to create the flow of current in the wire coils. This is accomplished by an iron wheel with a zig-zag slot in the side. The wheel is actually two pieces held apart by a non-magnetic strip of metal. The electromagnets affect the two pieces so that one becomes a magnetic north pole and the other a south pole. The engine spins the wheel between the coils and current is generated by the rapid change of north-south magnetism.

2. Lucas A.C. generator has rotating magnets in center of a ring of wire coils. Newer models are encapsulated in plastic to protect them from vibration.

3. Common A.C. generator on many two-cycle motorcycles. One coil supports ignition while the other supplies current for lights and horn.

ELECTRICAL

AC BATTERY COIL

AC (alternating current) generators are very simple. Consisting of little more than a series of connected wire coils arranged in a circle around a cluster of rotating magnets, they have no rubbing or touching parts. There is nothing to wear out such as the brushes and commutator in a DC generator.

But, as you remember in the first section on theory, not as much can be done with AC as with DC current. That was the reason for the commutator and brushes—it had to be converted from AC to the more useful DC electricity.

Then, along came solid-state electronics and transistor radios. By experimenting, scientists discovered that certain compounds of selenium had very strange electrical properties. They would allow electricity to pass in only one direction. The current could go forward but not in the reverse direction. Other compounds were found to freely pass electricity but only up to a certain voltage and anything over that was converted into heat. Many other unusual properties were found in other substances and soon the electrical designers were dreaming up ways to use these chemicals in electrical gadgets. They put these chemical compounds into tiny metal containers, stuck wires into the proper places and named them transistors, diodes, rectifiers and such. They are very useful things, very small, no moving parts and that means nothing to wear out. Although sometimes the chemical used inside is very expensive, there is such a small amount of it the price isn't high usually. These inexpensive, simple and reliable devices have had a profound effect on electrics and will, no doubt, continue to make things easier in the future.

One of the very first of these new solid state devices to find use on a motorcycle was the rectifier. It allowed the simple AC alternator to be used in place of the DC generator. That meant no more brushes to replace, no more worry about the commutator shorting out.

Rectifiers are made of the chemicals that allow electricity to pass in only one direction. It's like a one-way valve. A rectifier allows the half of the AC electricity going forward to pass freely. But when it tries to alternate (to go backwards) the rectifier stops it. The end result is DC electricity that comes in spurts. Half of the AC electricity is lost with this type of a rectifier which is called a half-wave rectifier.

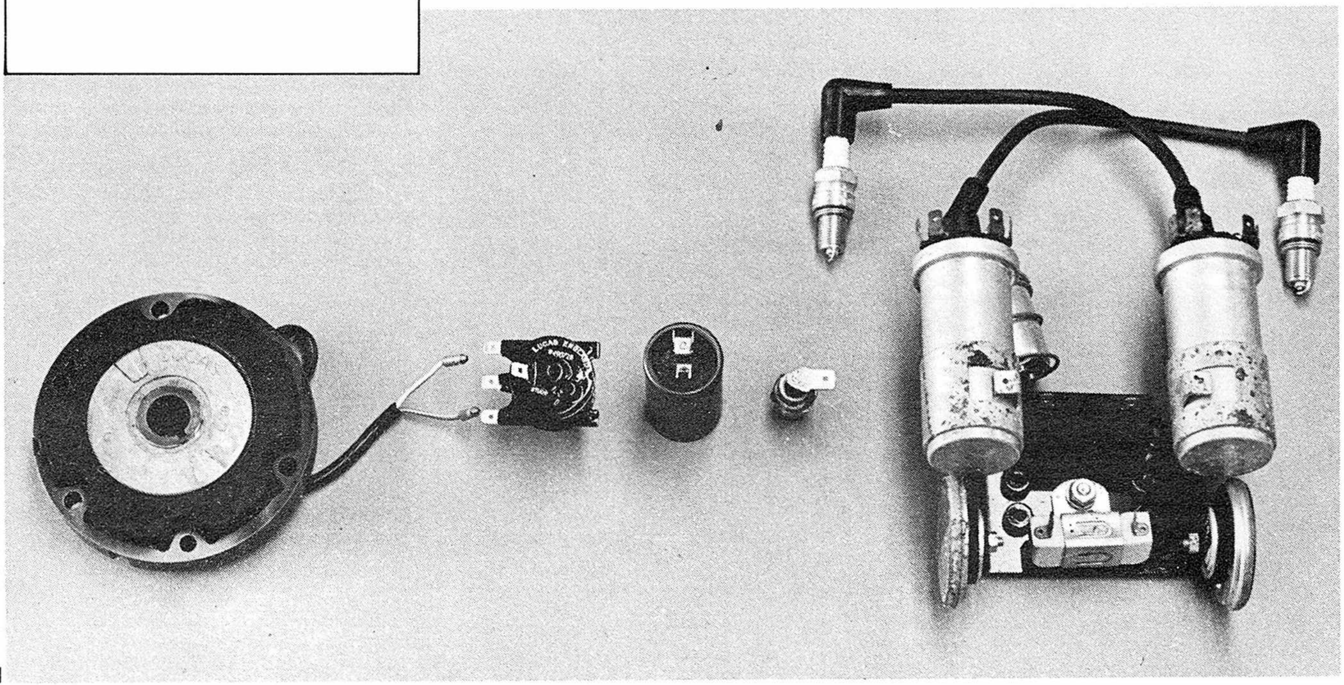
There is another type of rectifier which does a better job. You can probably guess what it's called: a full-wave rectifier. This type does everything that a half-wave does but goes a step further. In addition to allowing the AC electricity to pass in one direction, it opens up a new path for the AC in the opposite direction

1. In Lucas system, this capacitor will directly replace the troublesome battery with no alterations or modifications. Ignition will work normally but lights will dim at idle. Complete system is very simple. Principle is something like a D.C. energy transfer set-up. Zener diode must handle all the voltage regulation.

2. One of the first ignition systems to provide a hot spark: the magneto. Completely self contained unit was bolted to flange on engine and driven from crank through gears or chain. Contact breaker points are mounted on end of housing. Lever and cable on handlebar manually controlled the spark advance.

3. Two types of E.T. magneto rotors: inside and outside coil. Inside coil on left has a heavier magnet assembly and this acts as a flywheel. Outside coil is used on racing machines more frequently due to light flywheel effect.

4. Unit on left is oscillator from early Kawasaki 500. This converts the 12 volts D.C. through A.C. to 400 volts D.C. Triggering unit sends signal to SCR for spark.

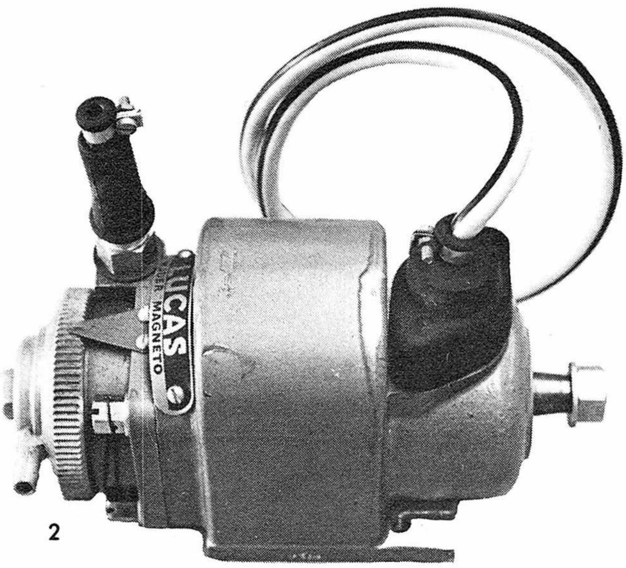


so that it can make a U-turn and join the other half. As the magnets spin past the coils, the north-south-north-south poles set up the alternating plus-minus-plus-minus current. The electricity is jerking back and forth inside the wires. As an example, let's say the rectifier allows the plus current to pass freely. As far as positive electricity is concerned, the rectifier isn't even there.

But when the current tries to reverse, the rectifier crosses the flow with the end result being DC current.

The full-wave rectifier wastes none of the AC electricity and is reliable until the day you hit it with a hammer. There is another advantage with the AC generator/rectifier combination. Voltage regulation is a great deal simpler. Because of the way the alternator coils are situated around the magnets, it's easy to run the wires from the coils up to a switch where they can be controlled before they are led to the rectifier. In this way, any number of the coils can be hooked into the entire system depending on how much electricity is needed. For instance, during the day when the lights are off, perhaps only two of the total six coils are needed. Then, when the lights are turned on, more coils can be switched into the circuit at the same time. This is possible (and is often done) by incorporating a double switch into the light switch. Two separate switches mounted in the same housing and operated by the same knob—one switch to turn on the lights and the other to connect the other coils into the system. Some of the older Hondas, Triumph twins and BSAs used this method of controlling the generator and protecting the battery.

It's a fairly good system, but it isn't automatic like the old electromagnet switch-type regulators. If the battery happens to be low on its level of charge, the rectifier won't do anything to correct this state. It will continue to run the system on only two coils in the daytime. And if the battery is fully charged, a small amount of current will flow into the battery and slowly overcharge it. English machines had a great deal of trouble with this. Chrome on mufflers and paint on the frames of many 1965 models was ruined by battery acid spilling over from overcharging batteries. It takes a very careful balancing of alternator coils and a large battery for this method to work well. When it's balanced right, it's trouble free.



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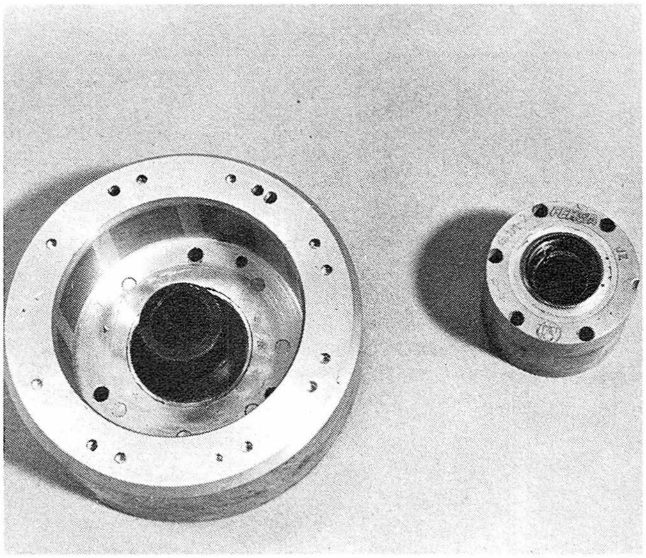

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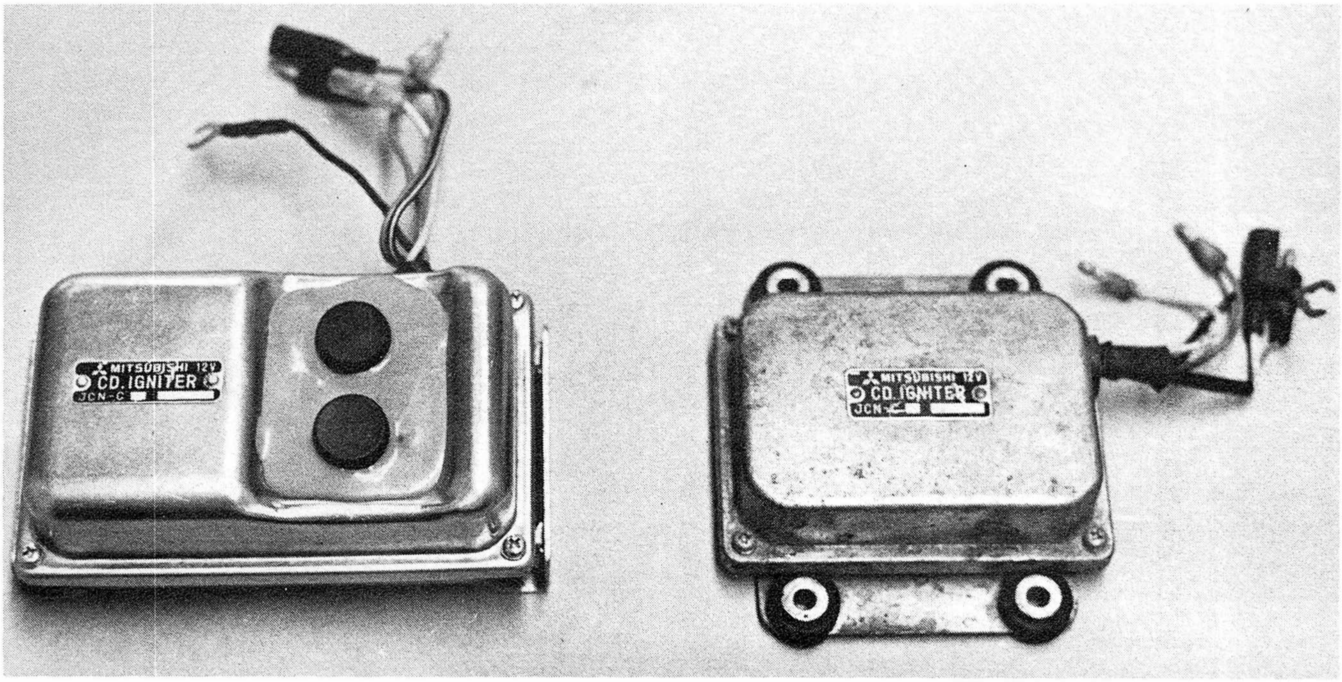

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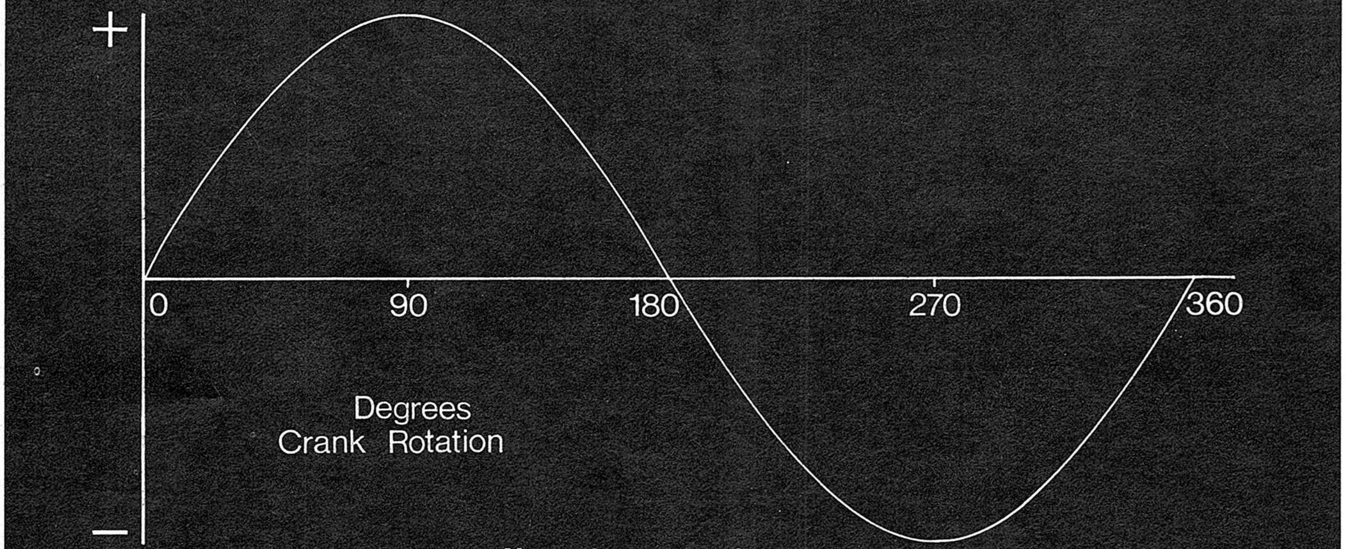
Then another of those solid state gadgets caught the eye of the motorcycle company's engineers: the Zener diode. This little electronic device will allow electricity to pass freely up to a specific voltage. When the incoming voltage exceeds that specific voltage, the diode chops the excess off, converts that into heat and allows the rest to pass as if nothing had happened. A 12-volt diode will ignore anything up to 12 volts. But if 14 volts tries to pass, it will knock two volts off and 12 volts will come out the other side of the diode. Sounds like it would make a perfect voltage regulator and that's what the engineers figured too.

However, it won't take too much excess voltage before it will melt itself. Generally about 10 percent over the rated voltage is the limit, which means a 12-volt diode can take 13.2 volts maximum before it will go belly-up. Most 12-volt alternators will produce something like 16 volts when the engine is operating up near its redline and that's more than enough to sizzle the diode.

It helps to mount the diode in an aluminum plate that has cooling fins built into it. Since heat is what ruins the diode, the mounting plate with fins (a heat sink) will help it pass off that killing heat. It helps even more to mount the diode and heat sink out in the airstream where it has a chance to cool better.

When a diode is added to the alternator/rectifier system, many of the overcharging problems disappear and the battery life is doubled. However, don't operate the bike with a bad battery. The battery (when it's in good shape) absorbs a lot of the extra current produced by the alternator and the diode takes care of the rest. When the two split up the extra electricity like this, both survive a lot longer. Without the diode, the battery will only last about a year. Without the battery, the diode will only last until the revs hit about 4500 and the voltage climbs up to 13.3 volts. For most of us, that means the diode is dead at the end of first gear! Those of you who have already sizzled one have discovered that some dealers charge $21.00 for

FIGURE 6



Alternating current sine wave

FIGURE 7

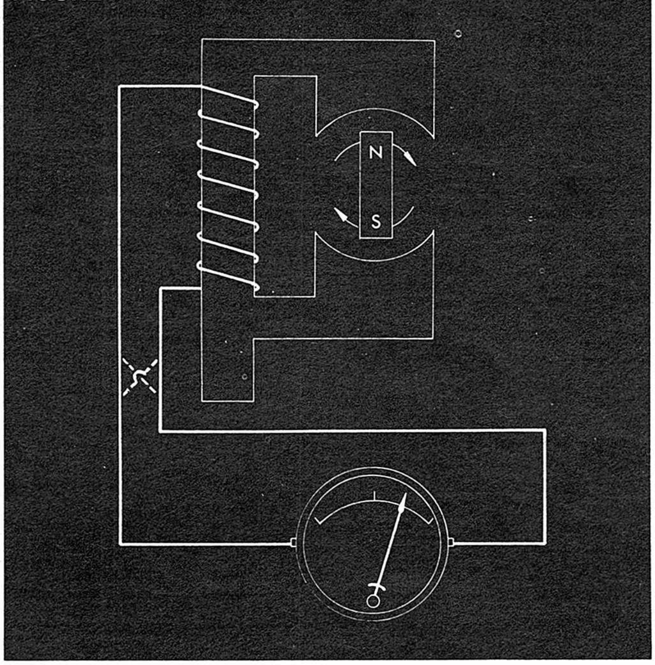
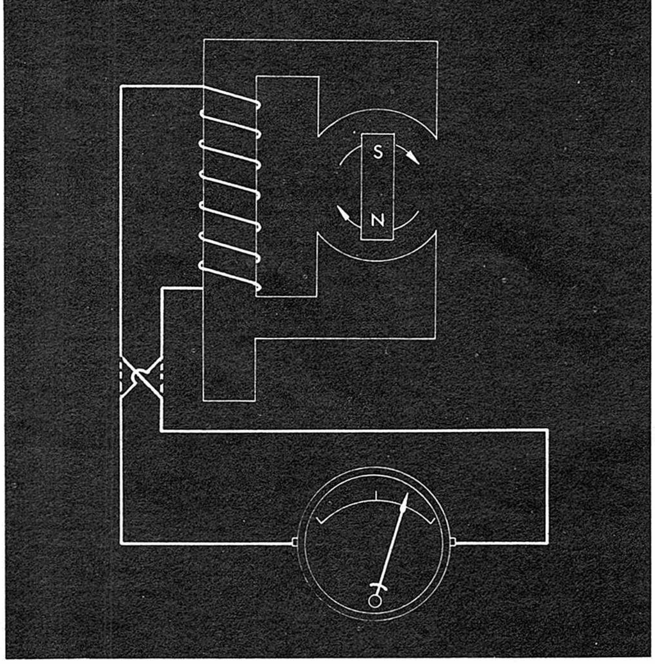


FIGURE 8



a new beauty—and installation is extra. You can save yourself a bunch of bucks by dropping by a local electronics shop. Pick up the heaviest duty 12.3 to 12.6 Zener diode he has or that he can order for you. The tab will be about $2.50. Better take in your owner's manual or a workshop manual (something with an electrical schematic in it) so that the man behind the desk can find you one with the right polarity and so that he has an idea of what you need.

With this type of a system, always keep a close eye on the water level in the battery. Don't let the battery lose its charge and deteriorate because that can ruin the diode. Also, keep the battery contacts clean. If they are corroded, the battery won't get a chance to take its share of excess voltage and pass it to the diode.

Troubleshooting either the DC or the AC generator/rectifier and battery system is not too difficult. Anytime one component in the system fails while the others work with no problem, you can figure that either the part (headlight, horn, turn signal, etc.) is no good or, more likely, a wire has broken or shorted against the frame. It always boils down to finding the faulty wire or replacing the part.

But, if the trouble lies in the power source, then it takes a little Sherlock Holmes thinking. It helps to know what the system will act like when each particular major component fails. When the generator quits or the rectifier is broken, the bike will run on only the battery and as the battery runs down, the bike will run worse and worse until it finally quits because there isn't enough electricity to operate the ignition coils. This state is easy to spot at night because the lights grow dimmer and dimmer. Revving the engine won't have any effect on the brightness either.

How do you know if it's the generator or if it's the rectifier? At this time it's very handy to have a volt-ohm meter. With this meter, the output of the generator can be measured and checked against what the shop manual says it should be putting out.

Alternators don't often go bad but when they do, their problem is generally a broken wire inside one of the coils. This may not stop the output of the alternator completely. It might still produce, but on a much lower level. That's why it's important to have the factory specifications handy when you take the readings with the volt-ohm meter.

FIGURE 9

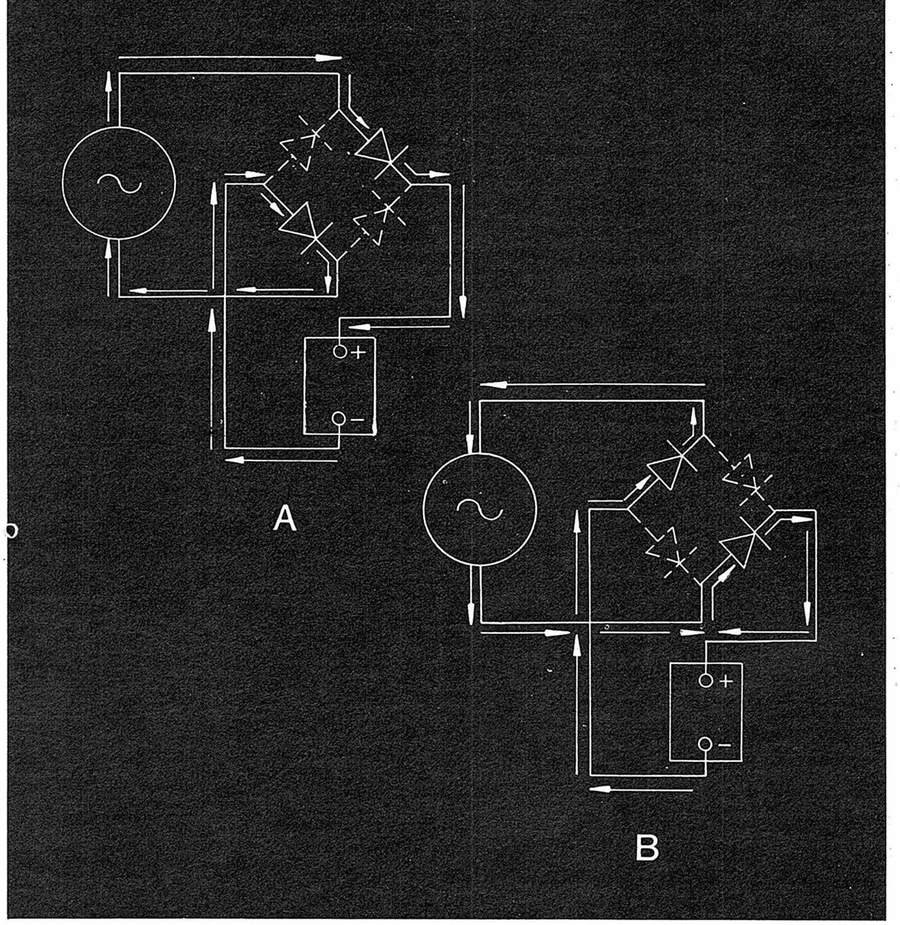
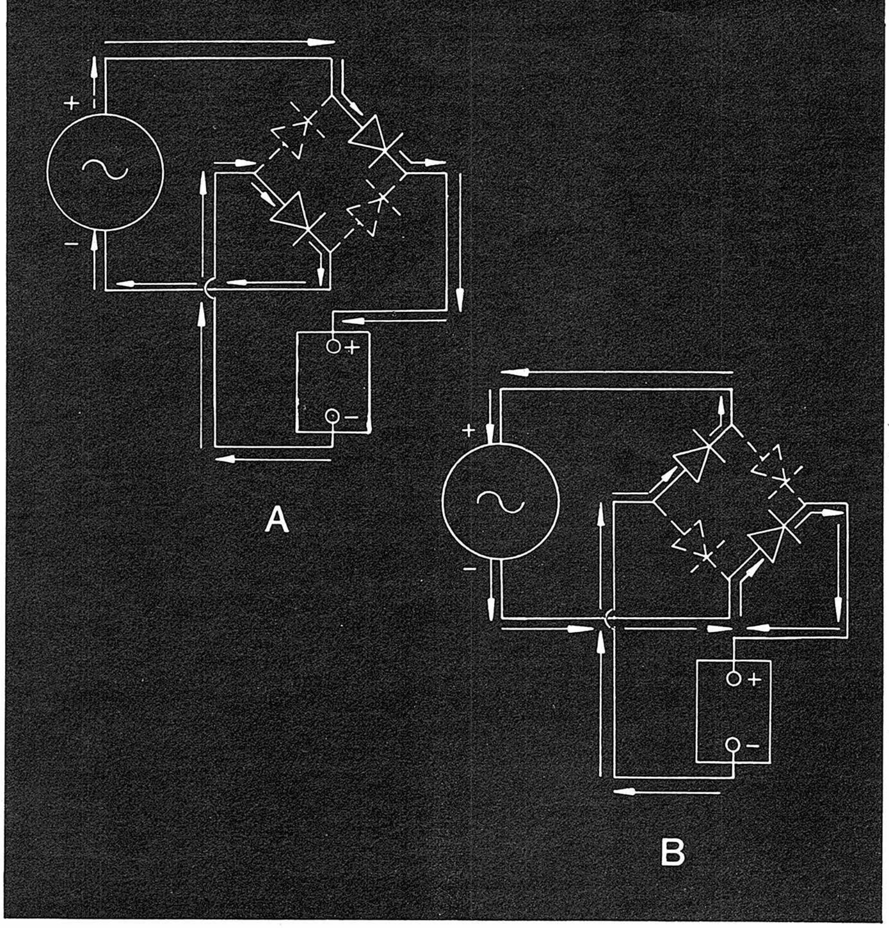


FIGURE 10



ELECTRICAL

Should the resistance readings be all right (which would indicate that there weren't any broken or grounded wires) but the output is still low, then there is the possibility that the magnets are weak. This is very rare, but it has been known to happen. Extreme heat or dropping the magnets on a hard surface can weaken them as can storing the magnets near another very strong magnetic force. More commonly though, connections will be loose or corroded.

After you've found the generator output high and the connections clean, what then, you ask? Elementary, my dear Dr. Watson—the rectifier, of course. If you wish, you might borrow the rectifier from a friend's machine of the same make and put it in place temporarily. There's really not much else that could be wrong if you've been careful with your test procedures up to this point. The only other possibility is the wire leading from the rectifier to the battery.

Suppose the bike is a bear to start and the light always goes dim when the engine is idling. The dimming light indicates that the battery isn't doing its job of providing a constant source of steady electricity. This may be due to a worn out battery or perhaps also due to a blown fuse on some models. Fuses are usually connected in series in the ground wire from the battery. If it blows, this would isolate the battery from the circuit. Some bikes will run like this, but most quit completely without the fuse.

A battery that is always slowly going dead in spite of recharging it in a shop could mean two things: The battery is on its last legs or that the alternator isn't running on all of its coils. In a situation like this, it's a good idea to check the alternator output first before replacing items blindly.

In almost every case of electrical problems, the trouble lies in something small. The major components don't go bad that often. Broken wires, bad connections and somebody's fat fingers stirring up the works sometime in the past are the most common bugaboos. Always work from a factory electrical schematic, work slowly and carefully. Most of all work with your head; think out what could be wrong from the way it acts and go from there.

E.T. FLYWHEEL MAGNETO

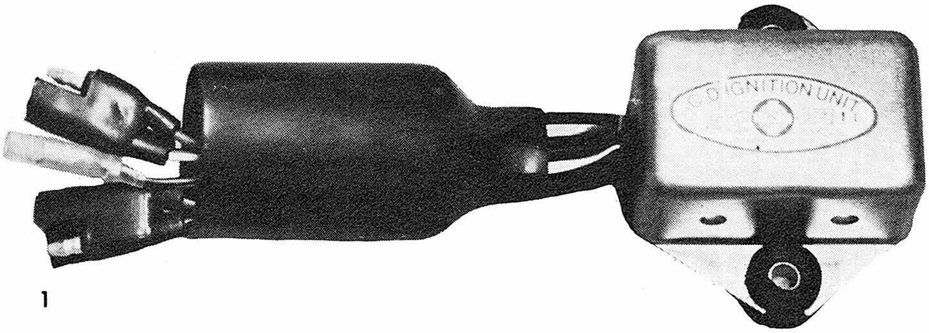
Way back in the old days, motorcycle engines ran on completely self-contained magneto ignitions. Everything was encased inside one housing that was attached to a convenient location on the engine. Gears or chain were used to take drive from the engine to turn the magneto and generate the spark. These magnetos worked very well, especially when compared to any other ignition system that was available at that time. They slammed out a 30,000-volt spark that is still envied today. However, reliability wasn't all that enviable. Magnetos had a tendency to fill up with engine oil that leaked past the mounting flange on the engine cases. And the drive train put a heavy strain on the bearings in the magneto and caused them to wear out rather quickly on some models, especially

1. "Black box" unit for generator supported CDI is small and simple. This unit, from Kawasaki 350 Bighorn, contains the capacitor and SCR which controls and supplies the spark.

2. The Bighorn flywheel/alternator rotor. Under the magnet flywheel are the coils for the lights, ignition, and trigger coil. Lighting coil is the largest and the trigger coil above the ignition coil is the smallest.

3. Femsa CDI unit, standard on many European motorcycles, is very simple and compact. This one has outside coils for a light-weight flywheel effect on fast revving competition engine.

4. Unusual magnet arrangement triggers Femsa unit instead of a separate trigger generator as on others such as Kawasaki 500. Note inside coils and heavy magnet wheel for street bike.



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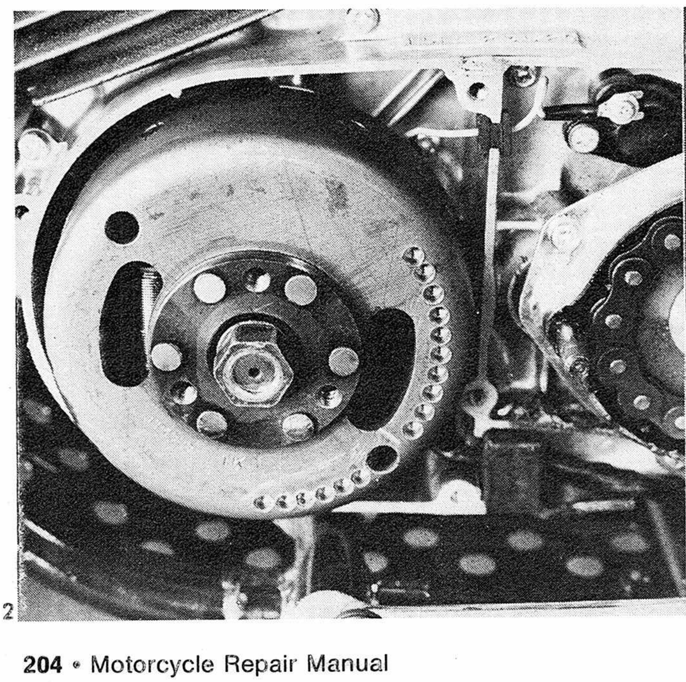

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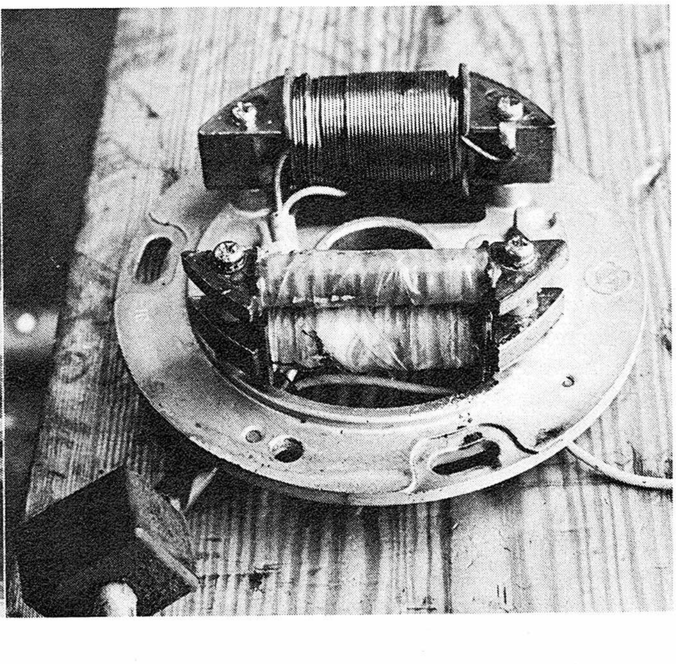

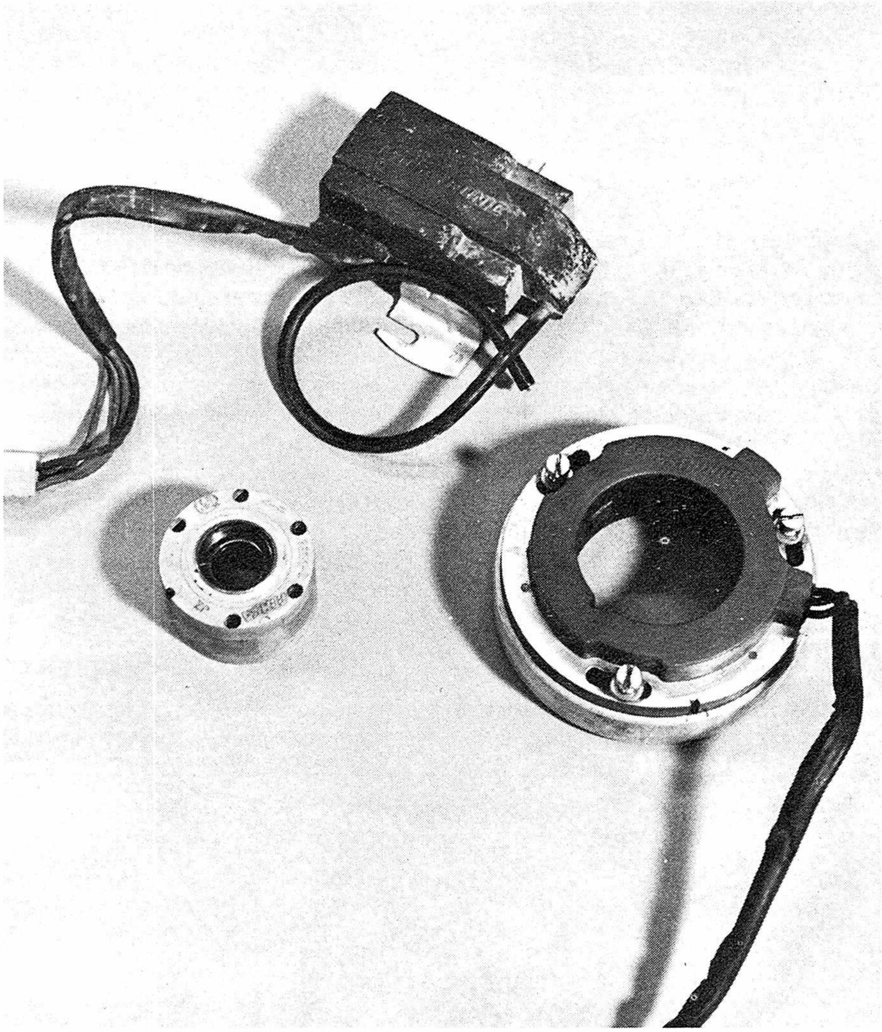

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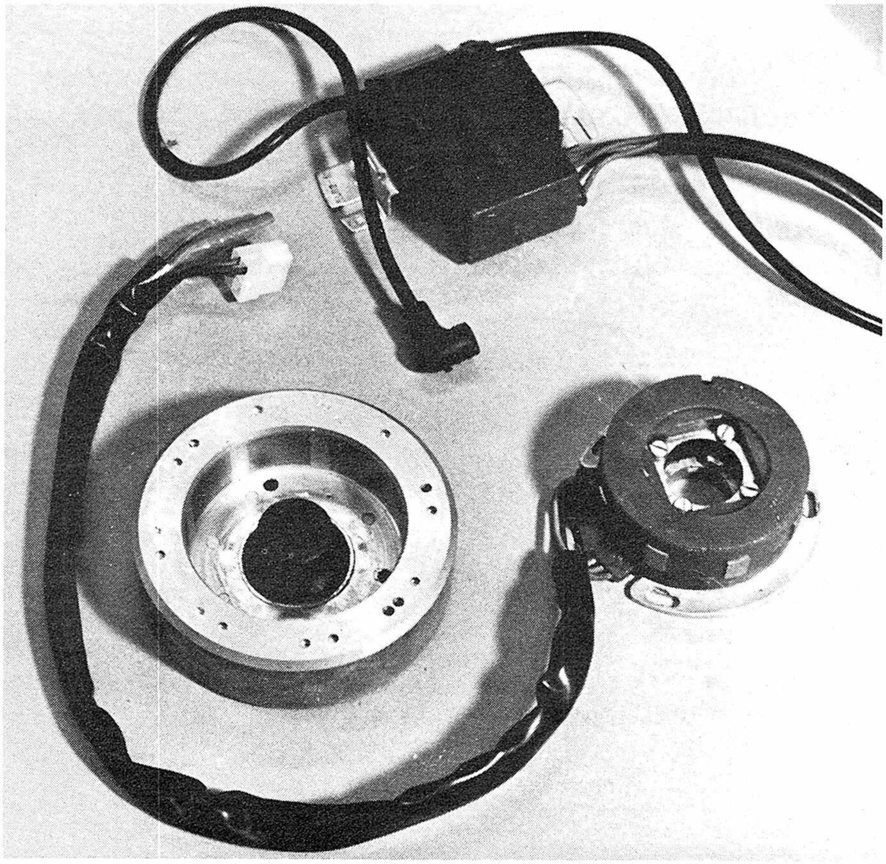

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those with chain-driven mags. But their very hot spark ensured their popularity for many years. In fact, they are still considered the hot set-up in many racing fraternities today.

But engine designers decided to clean up their creations and move components inside where possible. The magneto's turn came almost last and when it did, the designer split it into two pieces. The low-tension half of the magneto, which is mounted to the end of the crankshaft, looks almost identicai to an AC alternator. Wires lead from here to the high-tension half of the magneto which is usually mounted under the gas tank. The Lucas E.T. (energy transfer) system is a good example of this type. It is one of the few systems that produce the voltage for the spark by the sudden *appearance* of an electromagnetic field reather than the disappearance of it. All that is important is a change in magnetic influence to produce the spark. If the appearance is sudden enough, it will do the job.

Of the six coils of wire in the alternator, four are for the ignition and the remaining two support the lighting system. Except for the fact that they operate around the same magnets, they are completely separate and operate independently of each other.

The AC generator serves as the source of electricity for the entire system; there is no battery. Because of the nature of the alternator, the current flow isn't steady. It has high and low spots in the voltage. Each time a magnet swings past a wire coil, there will be a burst of electricity followed by a lull until another magnet swings by.

Lights aren't affected by this rapid fluctuation. They will operate in a normal manner. But the ignition is another story. As you remember, an electromagnetic field is built up around the coil of very thin wire in the high-tension coil. The contact breaker points open and that field changes suddenly which produces the voltage needed for the spark plug. The E.T. system has pulsating electricity and if there is a dead spot in the current occurring right at the moment the points open, there won't be any current creating a magnetic field. With no magnetic field to change, the breaker points accomplish nothing and there are no 20,000 volts and no spark. The rotating magnets in the alternator have to be positioned so that the magnets swing past an igni-

tion supporting coil at the moment the points open. This will ensure that a strong pulse of electricity is in the ignition coil creating a good electromagnetic field. Now, when the points open, that magnetic field will appear and produce a good spark.

This brings up one of the characteristics of an E.T. magneto: It is very difficult to retard the spark for easier starting as can be done with a battery operated ignition. This is because retarding the spark would mean opening the points at a slightly later time than usual and that point in time wouldn't have a strong pulse of electricity for the electromagnetic field. Whereas battery operated ignition is usually set up for about 25 degrees of retard at idle, the E.T. can only take 10 degrees before the spark fades.

English twins running the E.T. have arranged the system so that all four alternator coils supporting ignition feed to the high tension coil that is about to fire. The other coil is cut out of the system and "ignored" until its turn to fire comes around. This means that each high tension coil is fed a heavy jolt of current and it can produce a hot spark.

The E.T. ignition system is very simple and troubleshooting it is easy. There are actually only three components to check out: The alternator, the high tension coils and the breaker points. All of these are relatively trouble free and in the event of trouble, first check the points and then look at all the wire connections. The alternator has nothing to wear out and the wires in the coils don't usually break. The newer alternators are sealed inside a plastic armor and this helps hold everything tightly. Vibration is no longer a problem. The high-tension coils are also sealed in plastic but there has been a small problem with vibration breaking the wire leads where they exit the plastic. It's not usually possible to solder the leads back and the coil must be replaced.

It has been found that the Lucas E.T. is very sensitive to the breaker point gap. If the engine starts missing and becomes hard to start, the first place to look is in the points.

Many of the Japanese bikes, particularly the smaller ones, use an E.T. system. However, they will also use a battery to help the lighting system. The ignition still operates directly from the alternator as in the Lucas E.T. The lighting coils in the alternator are connected to a rectifier which in turn supports the battery. The advantage to this system is bright lights, even at idle. Also, some states now require that the taillight be capable of operating for a minimum of fifteen minutes without the engine running and this is only possible with a battery in the circuit.

Four-cylinder Hondas have an interesting variation on the E.T. system in that only two high-tension coils supply the spark for all four cylinders. Honda's coils have double spark plug leads and two plugs fire from each coil. This necessarily means that both plugs fire simultaneously. The system is arranged in such a way that while one plug is igniting fuel/air in a cylinder, the other plug is firing harmlessly in a cylinder that is on the exhaust stroke. The only disadvantage to this set-up is if one plug is defective and fails, the other plug will not fire even though there is nothing wrong with it.

CAPACITOR OVER BATTERY

In a standard battery/coil electrical system, the battery's role is to provide

FIGURE 11

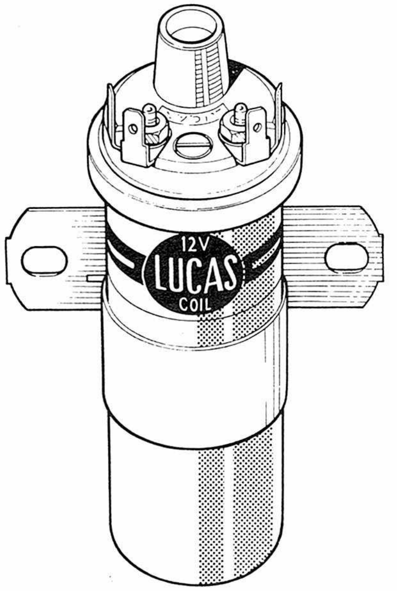


FIGURE 12

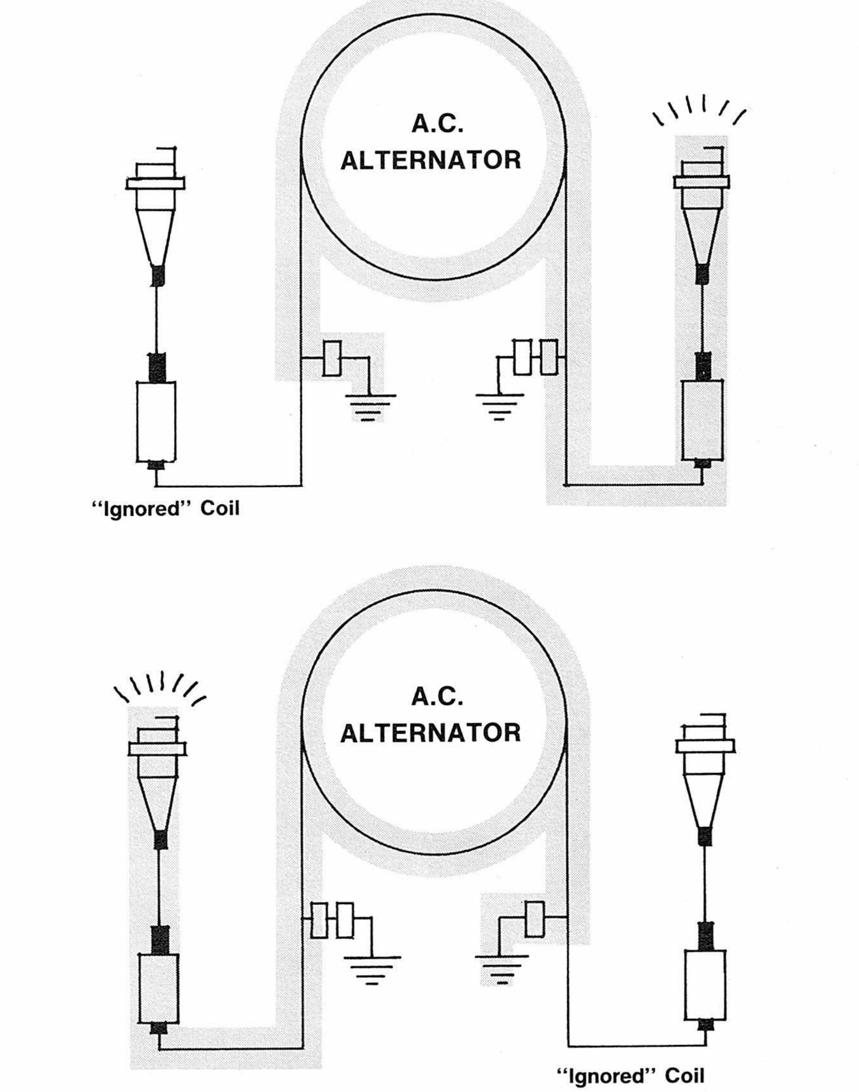


FIGURE 13

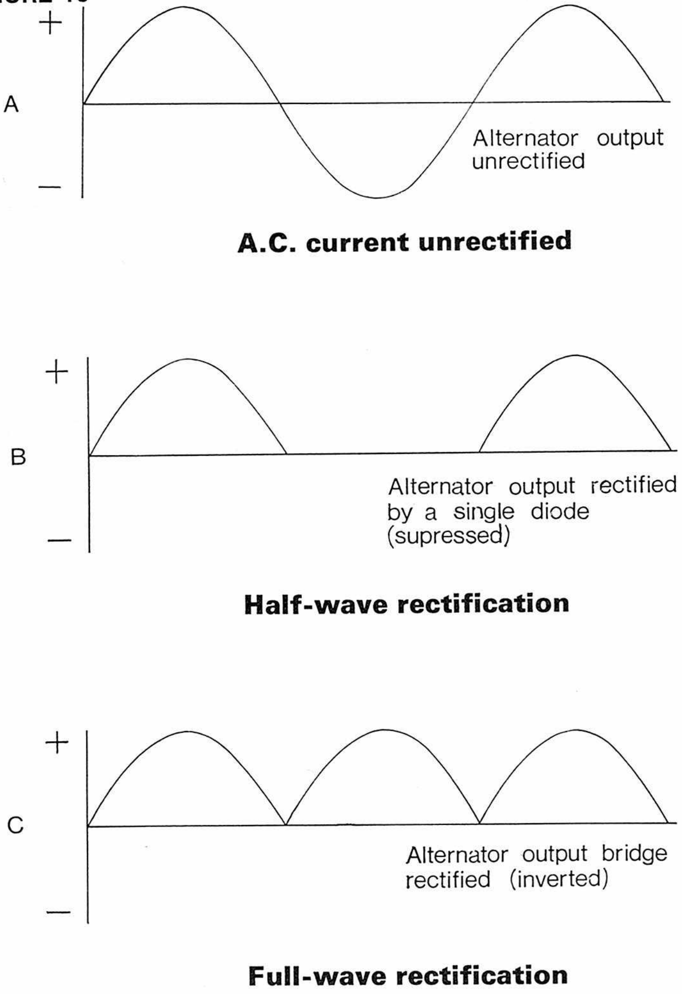


FIGURE 14

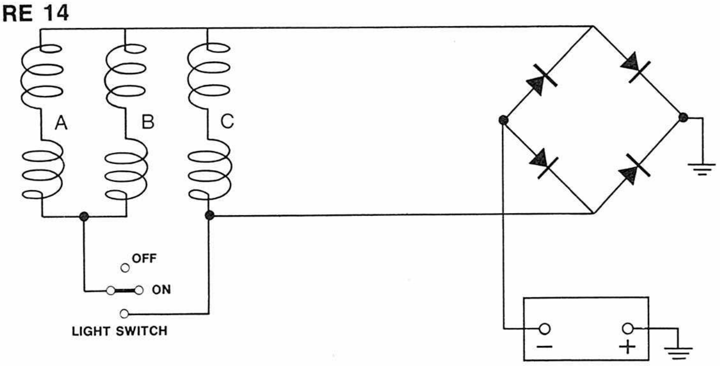
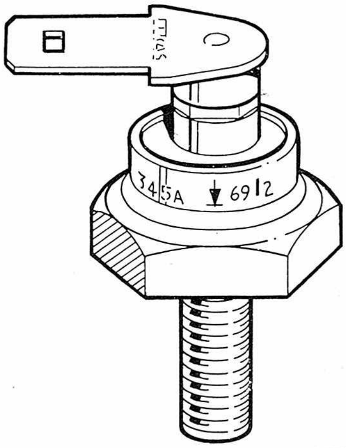


FIGURE 15



a steady supply of current. One of its secondary roles is to provide a means of voltage regulation. Any excess current produced by the generator is absorbed by the battery and converted to heat inside the battery. (It is this heat that causes a battery to "boil over" when overcharged.)

Batteries have always been a problem. They are large and heavy in addition to being a nuisance to maintain. Bike customizers and individuals involved in racing have come up with various means of eliminating the ugly, bulky thing.

One of the more popular means in recent times has been to use a capacitor in conjunction with a Zener diode and, occasionally, some resistors. There are two reasons why the battery usually can't just be removed. The first is voltage regulation. Without a battery, the generator's current would flow unchecked into the system. Light bulbs would blow out anytime a shift was missed and the entire circuit would be overloaded most of the time.

The second reason is due to the characteristic bursts of current produced by any generator—it isn't a steady flow but has rhythmic "dead" spots in it. The current flows in a rapid on-off-on-off-on-off manner. Lights aren't affected by this fluctuation in a way visible to the naked eye. In fact, as you may know, household lights flicker in this same way all the time and is not visible.

But the ignition coils may have a problem doing their job with this "on-off" mode. Everything will work as long as the current is in the "on" position. The electromagnetic field can be set up and then collapsed by the breaker points for the spark. But if the current is in the "off" position when the spark is needed, there's a problem—no spark. Normally, this is where the battery would support the system and everything would function in spite of the dead spot.

Here is where the capacitor comes in. It is another solid-state gadget, although capacitors have been around since the ancient days of static electricity. Back then they were known as Leyden jars. Modern capacitors are cylindrical in shape and vary in size from ⅛-inch to more than two inches in diameter. Inside, it looks like a jelly roll made of aluminum foil and a paper-like insulator.

If you connect a battery to the two terminals on a capacitor, there will be a flow of electricity into the capacitor for only an instant and then it will stop flowing. The battery leads can be removed and still nothing happens. But touch a wire across the capacitor terminals and there will be a little zap of electricity. The capacitor holds a charge of voltage inside. A good quality one will hold it for several min-

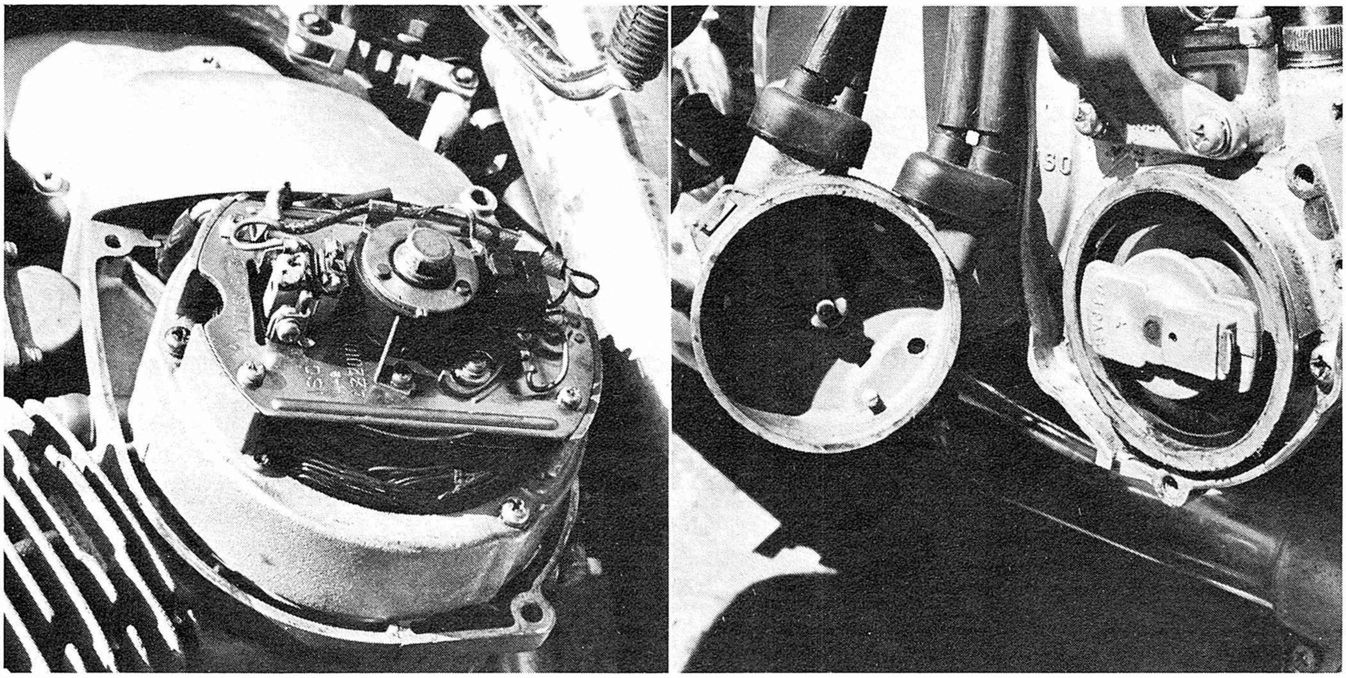
utes before the charge fades away.

Probably in just about every motorcycle shop in the country, practical jokers have charged up the small ignition capacitors (also called condensors) and left them lying around for unsuspecting souls to pick up. The joker has a big laugh when the victim touches the terminals and is zapped.

Aside from practical jokes, capacitors can serve a very handy function in an ignition system. This ability to hold a charge can be put to use to fill in for the "dead" spots in a generator's output. The capacitor is charged up by one of the bursts of current from the generator. When it comes time for the spark, should there be a "dead" spot, the capacitor in the circuit releases its charge and the ignition coil is zapped in spite of the generator's flat spot. Very handy. Plus, no battery acid to spill over.

However, there is still the problem with voltage regulation. Straight battery/coil systems may find that the lighting circuit can't take the generator's output without the battery in there to absorb the excess voltage. Light bulbs may have to be bought by the carton to keep the lights going.

Systems with battery and Zener diode to share the overload will find that the Zener alone usually can't



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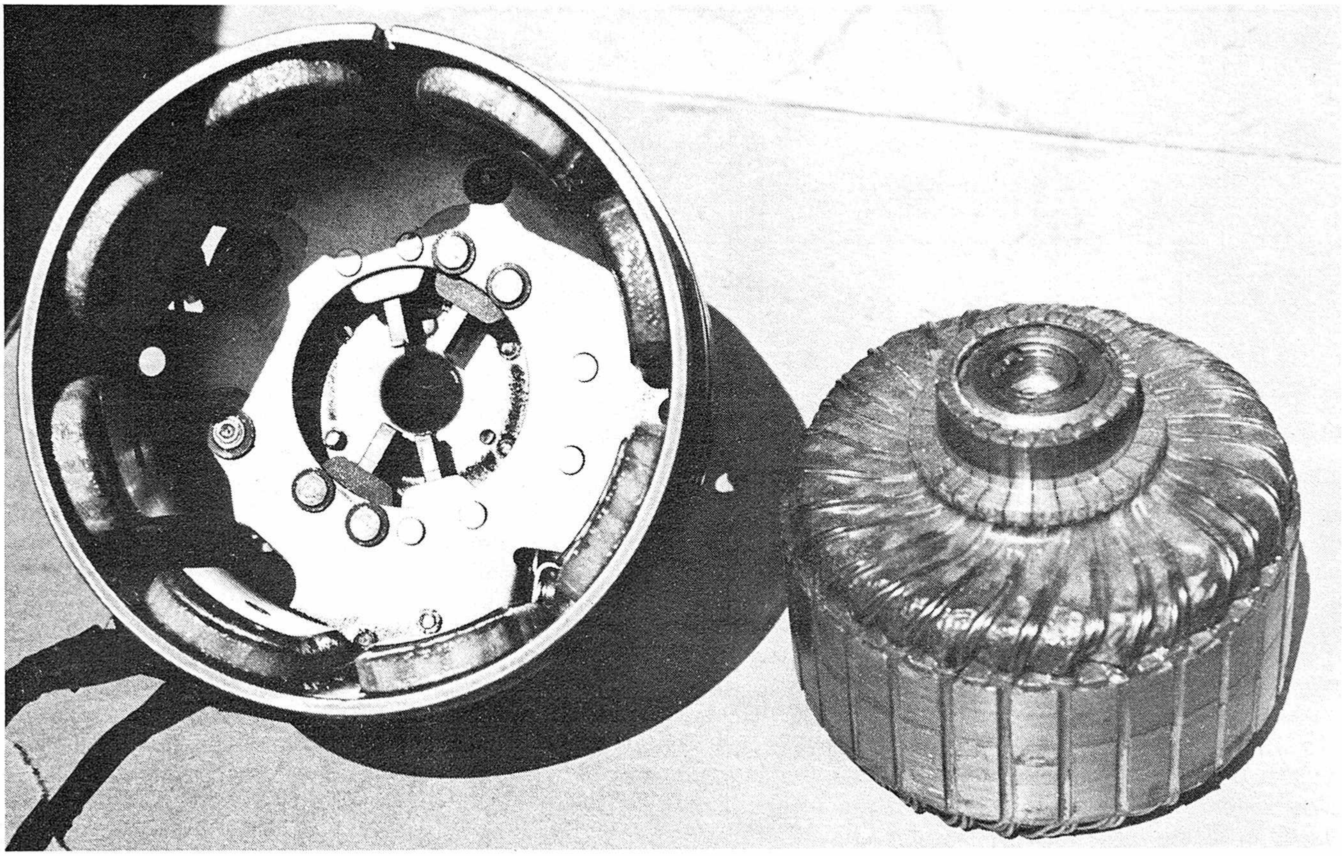

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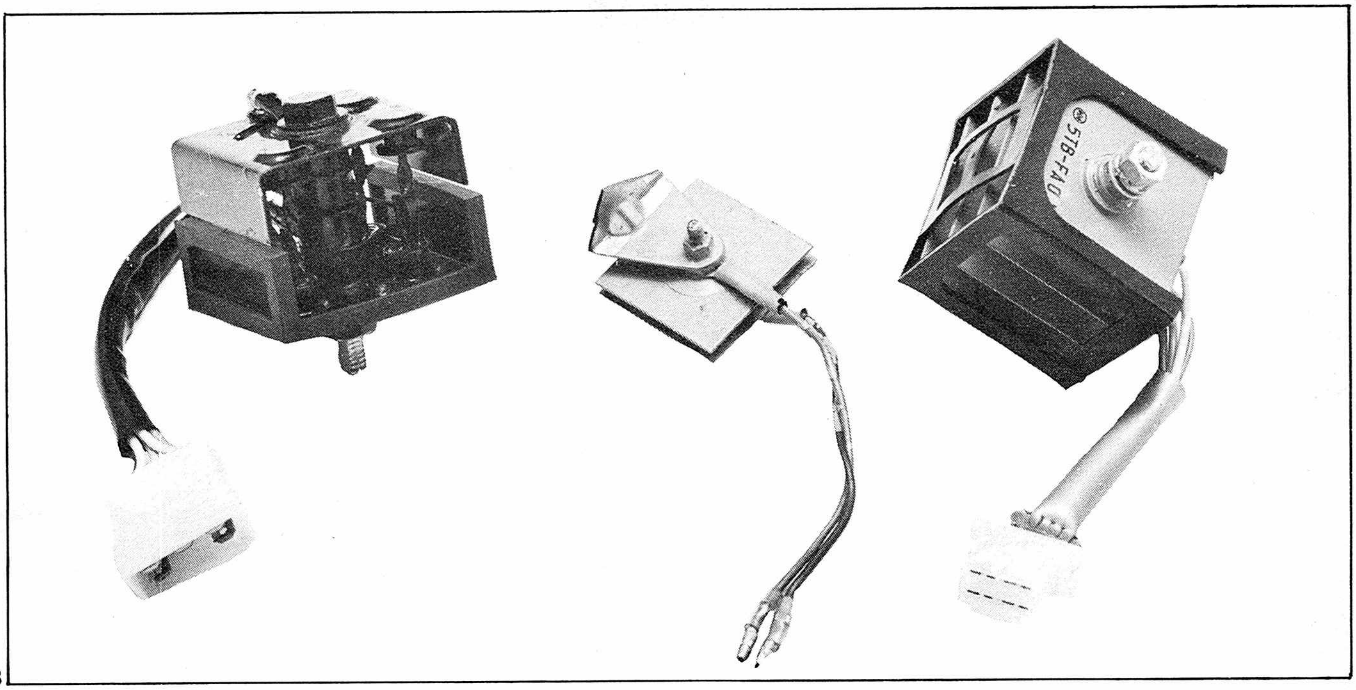

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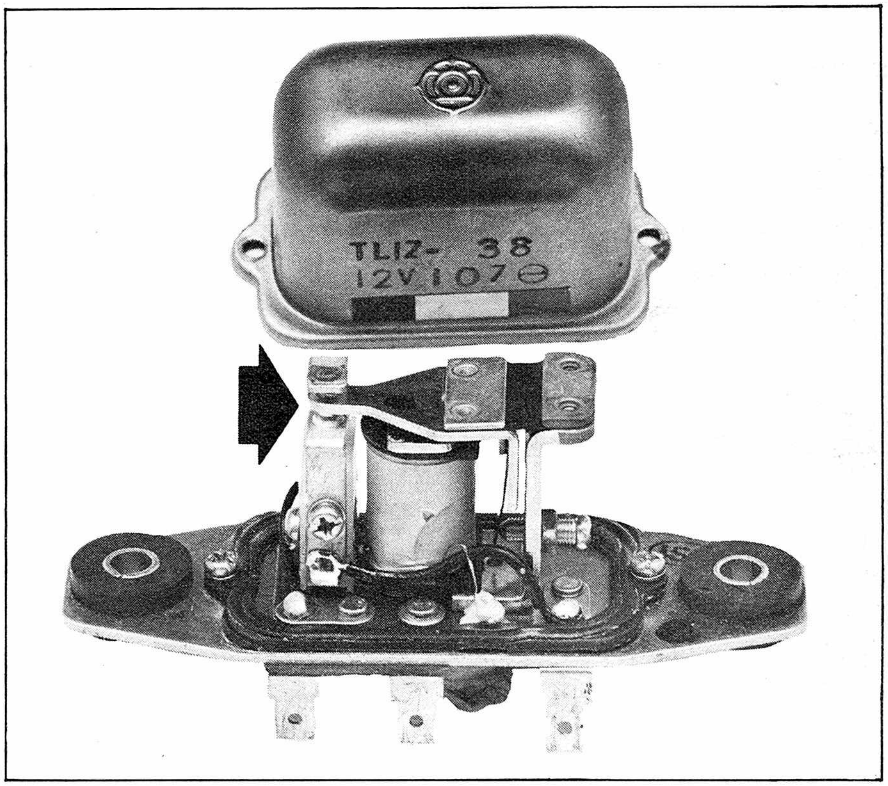
1. Trigger generator on early Kawasaki 500 triple. Three small magnets each spin past a coil which sends jolt to unit "A" under the seat and triggers spark. Distributor on right side of engine switches 30,000 volts to appropriate spark plug. New models have three separate ignition systems supported by a common generator.

2. Yamaha 125 enduro utilizes a combination starter motor/generator. Generator is D.C. type and has commutator and brushes. Two brushes are for starter motor and other two are for generator operation.

3. Two types of Honda rectifiers. In the center is a half-wave type surrounded by two models of full-wave rectifiers. All are very rugged and seldom give any trouble.

4. Battery controlled, electromagnetic type of voltage regulator. Arrow points to contact points which may need cleaning with a point file if corrosion exists on the faces.



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handle the overload. Then the same problem as above will come up—bulbs will blow frequently. Most systems will utilize Zener diodes and perhaps a few resistors inside a "black box" to help with the voltage regulation.

Battery eliminator kits have been offered for sale as accessory items for a few years now and this is all that they are, basically. The new Nortons and some of the BSA 500 singles come standard with a capacitor in place of the battery. In the Norton, for example, there is no "black box." The Zener diode normally used in conjunction with the battery will withstand the overload as long as it is mounted in a good heat sink out in the airstream. (Since some states have a "parking light law" which necessitates a battery, all of the connections have been left in place.)

Most people, when they kick start an engine, will rotate it up against compression and then kick it over. This means that the plugs will attempt to fire immediately. Because the capacitor isn't charged up (the engine hasn't yet been spun over fast enough for the generator to put out a good jolt), it is very unlikely that the engine will start on the first kick. There won't be any spark. A very strong person might be able to kick it hard enough for two revolutions and it could start for him. But the normal man will have to kick the Norton twice to set it running; once to charge the capacitor and again to fire it.

Troubleshooting is pretty easy. It works or it doesn't. There's the possibility that the generator is in phase with the ignition. (That means that a burst of electricity is produced at the moment the points open.) The engine would run under this condition, even with a faulty capacitor. However, it would either idle but throttle would

cause it to die, or run but not idle. This is because the burst of electricity doesn't cover a long enough period of time to fire both ends of the ignition advance and retard positions. If you weren't sure whether the capacitor was any good, you might charge it up with a battery and leave it lying around for some poor soul to pick up but you'd better make sure he's smaller than you and doesn't know any karate.

CAPACITOR IGNITION, BATTERY SUPPORTED

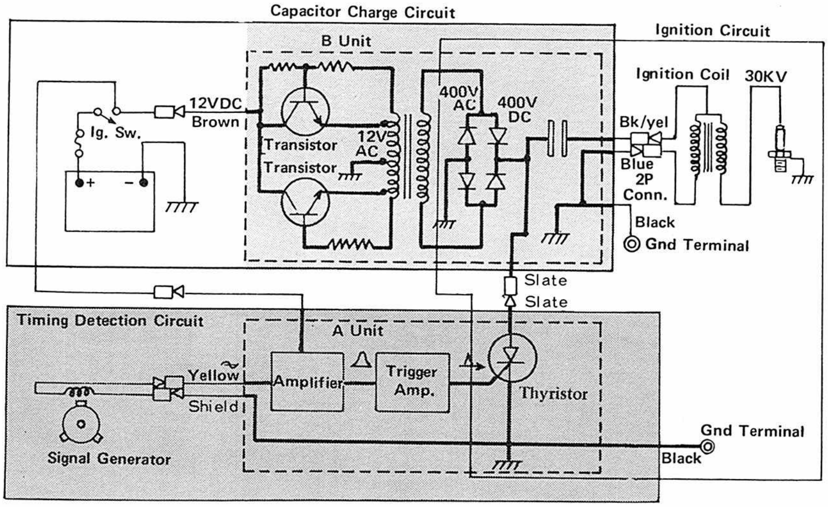
The electronics designers took a look at the capacitor and saw some other advantages in applying it to ignition systems. When a charged capacitor unloads, it does so instantaneously. The entire charge zaps out all at once. They realize that this kind of a zap would do twice as much good in an ignition high tension coil as would the same charge released in a slower manner as in a conventional battery/coil system. It is the *change* in electromagnetic field that produces the spark and if the change is more sudden, then it is more effective in producing that spark.

This was tried and it worked, although nothing really spectacular occurred, so it was decided to increase the voltage going into the high tension coil and set up a bigger electromagnetic field. They were faced with a number of possible ways to increase the 12 volts coming from the generator. One way was to convert the 12 volts DC into 12 volts AC and then run it through an AC transformer. This is the way it was done on the first Kawasaki 500 triple. The DC to AC conversion is done through an electronic gadget called an oscillator. An explanation of how it works is delving pretty deeply into electrical trickery. Rather than confuse the issue here, just let it be understood that the thing does it.

The transformer works on the same principle as the high-tension coil. A changing electromagnetic field produces electricity in a nearby coil of wire. The 12 volts AC powers the electromagnet. Because it is AC, the rapid plus-minus-plus-minus characteristic reverses the electromagnetic field everytime it changes direction. Reversing the field is a change and this produces a current in the nearby coil.

Whereas an ignition high tension

FIGURE 16



Early Kawasaki H1 500cc three CDI system uses an oscillator in unit "B" to kick the 12 volts D.C. to 400 volts D.C. It passes through an A.C. stage in doing so. Unit "A" is the triggering system. The signal generator sends in a tiny jolt which is in turn amplified (made bigger) and this is fed to the thyristor (SCR). It controls the 400 volts D.C. that generates the 30,000 sparkplug voltage in the high tension coil.

Kawasaki used a distributor to control the firing order. It is a simple switch that feeds the 30,000 volts to the appropriate sparkplug.

FIGURE 17

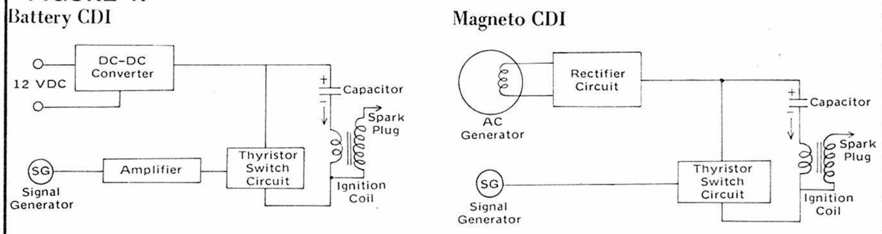
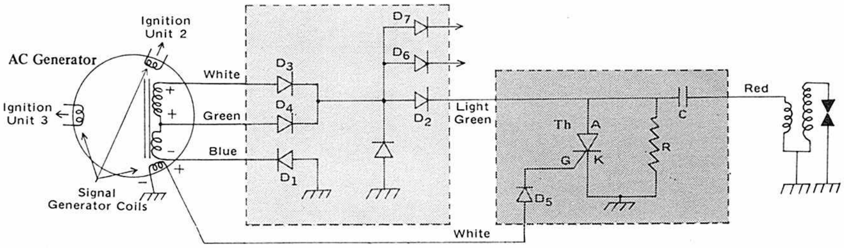
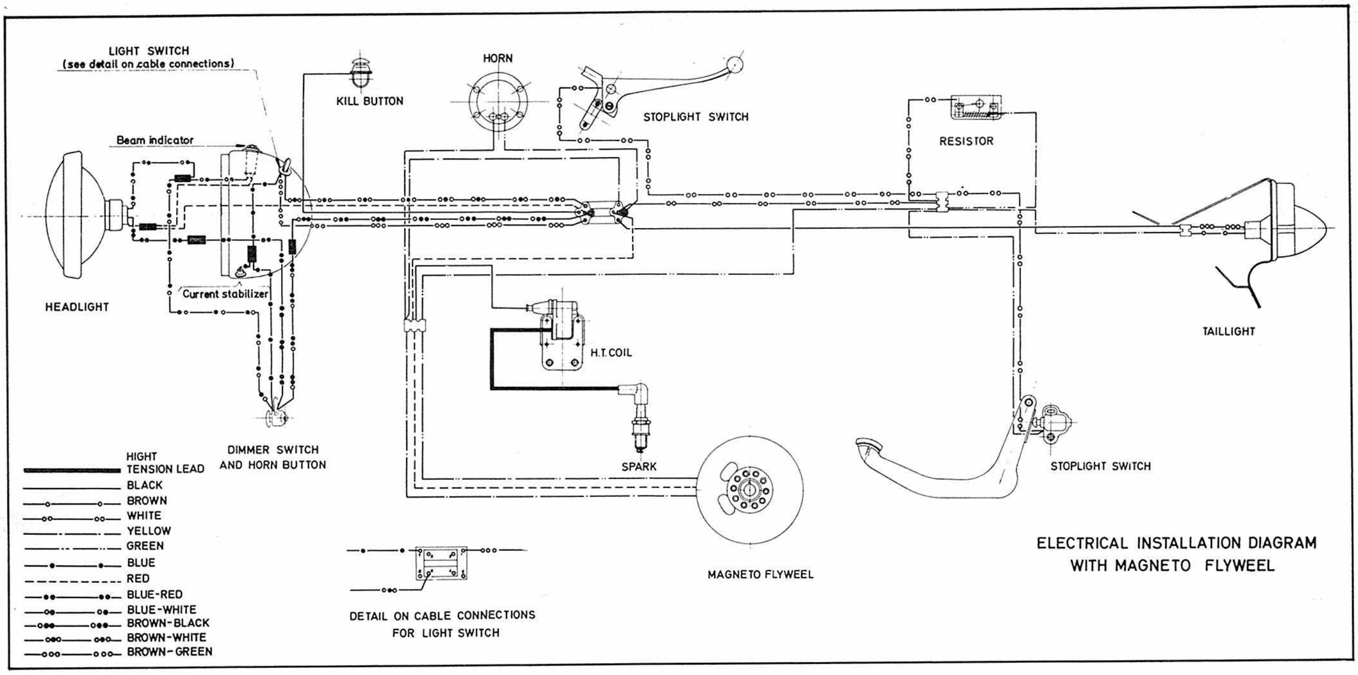


FIGURE 18

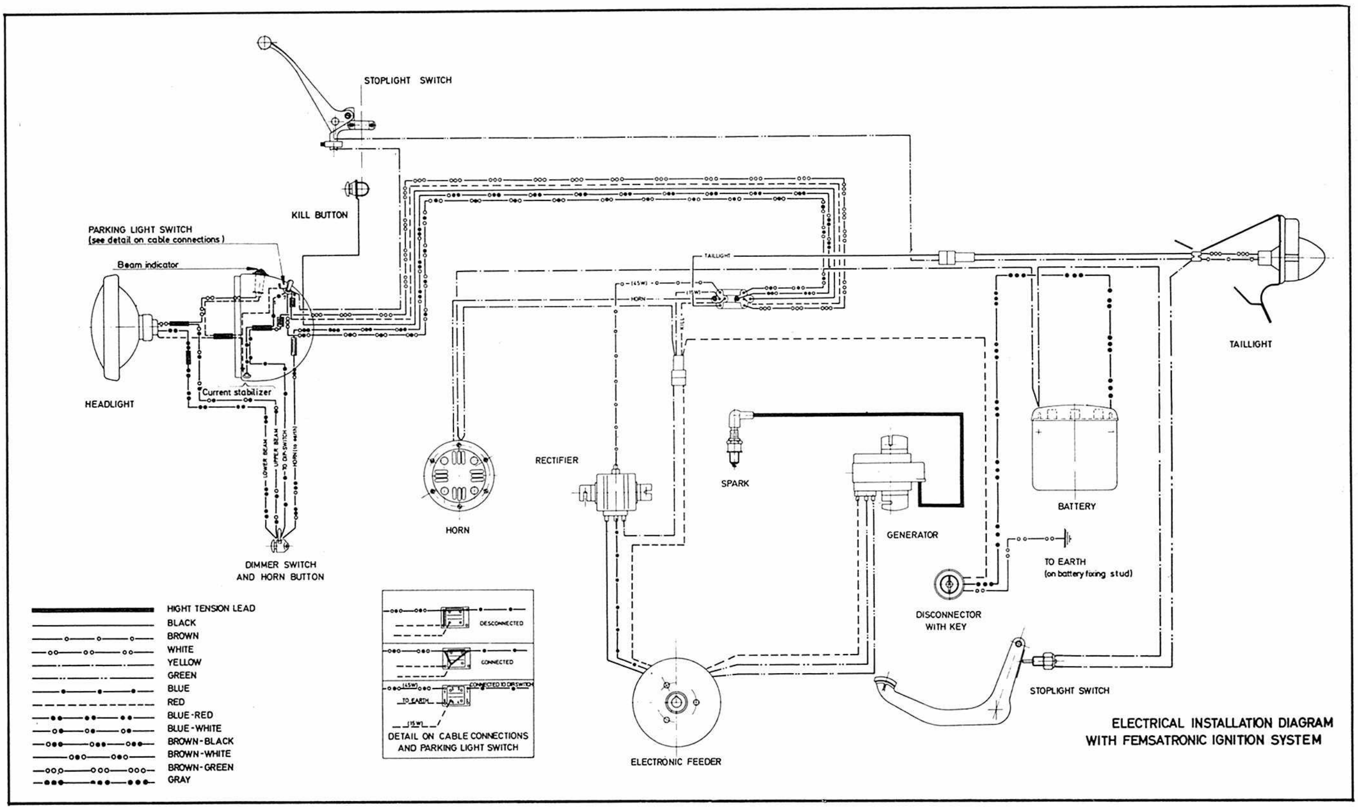
Magneto CD Ignition System



New '73 models in the Kawasaki line will have this magneto CDI system. The light grey area is the rectifier for the 400 volts coming from the alternator. This then feeds the capacitor in the darker area. The signal from the trigger also feeds to this "black box" which contains both the capacitor and the thyristor (SCR). There are three identical ignition units, each with its own capacitor and SCR which supplies current to three high tension coils to generate the spark.



ELECTRICAL INSTALLATION DIAGRAM
WITH MAGNETO FLYWEEL



ELECTRICAL INSTALLATION DIAGRAM
WITH FEMSATRONIC IGNITION SYSTEM

coil uses the contact breaker points to collapse the field and produce the current, an AC transformer uses the alternating current to change the field and produce the current. This is convenient because there aren't any moving parts to hassle with.

The second coil in the transformer must be made up of very thin wire. If the second coil were the very same size of wire and the same number of loops, the output would be nearly the same as the input, 12 volts in and 12 volts out. By using the smaller wires and putting on more loops, the voltage is increased. This doesn't really mean that more electricity is being produced, only its form has been changed.

Output from the transformer is 400 volts but it is AC. It now needs to be converted back to DC for the capacitor to be able to work with it and that is a job for a rectifier. As the 400 volts DC comes out of the rectifier, it is fed into the capacitor and held there for the high tension coil when the time comes. A total of 400 volts has a lot of squirting power behind it and it doesn't work well in a contact breaker system. When the points open, the electricity keeps right on jumping across the gap. No spark at the spark plug.

But the electronic people already had this one figured out. There is a solid state gadget that has an interesting characteristic: It won't pass any electricity, not even a big charge, unless the side of it is touched with a tiny dab of current. It's like a heavy-duty electric switch that is activated by another smaller electric current. Perfect for the job. This gadget, called a thyristor or a silicon-controlled rec-

tifier (S.C.R.), would be used to control the 400 volts stored in the capacitor for the high tension coil. Just touch it with a small current when the time is right for ignition.

The engineers could have used the battery current to activate it through a set of contact breaker points but that involved using the same old parts which were still prone to getting out of adjustment. Because the voltage required to activate the SCR was so small, it would be possible to make a little generator with only one coil of wire and one magnet. This generator would produce one small jolt per revolution. Mount the generator to the engine in such a way that this jolt occurs when the spark is needed, feed it to the SCR and the ignition is complete. No moving parts and a super spark is produced—about 30,000 volts.

This is basically the way the first model of the Kawasaki 500 received its spark. It was a bit cumbersome because of all of the converting going on. This intricacy also makes it nearly impossible for any troubleshooting on the part of the owner. It takes sophisticated test equipment to check it out in the event of a malfunction. About the only thing that can be checked for are loose wires or shorts. If you have a friend with a running bike, you might try switching components until you come up with one that works. Then go buy a new part at the dealer.

CAPACITOR IGNITION, MAG SUPPORTED

After one studies the battery supported capacitor ignition for a time, an obvious question comes up. Why not use a generator wound with many loops of very thin wire to supply the 400 volts of AC? The end result is exactly the same as using a battery-oscillator-transformer arrangement and that result is achieved without all those components and expense.

This is the only basic difference in the two types of capacitor ignition systems. From the rectifier on, they are the same in theory and principle. The new Kawasaki 500 triples will have this newer style of simplified system.

The strong, hot spark has proved popular for use in two-cycle motorcycle engines because of resistance to spark plug fouling. The Femsatronic unit, used on Bultacos, is typical of those found on competition and enduro machines. Femsa encapsulates the capacitor, rectifier and miscellaneous components in a plastic block along with the high tension coil. It's convenient having everything all in one spot, no clutter on the bike and this simplifies installation but it does make repairs a bit on the expensive side if anything goes wrong.

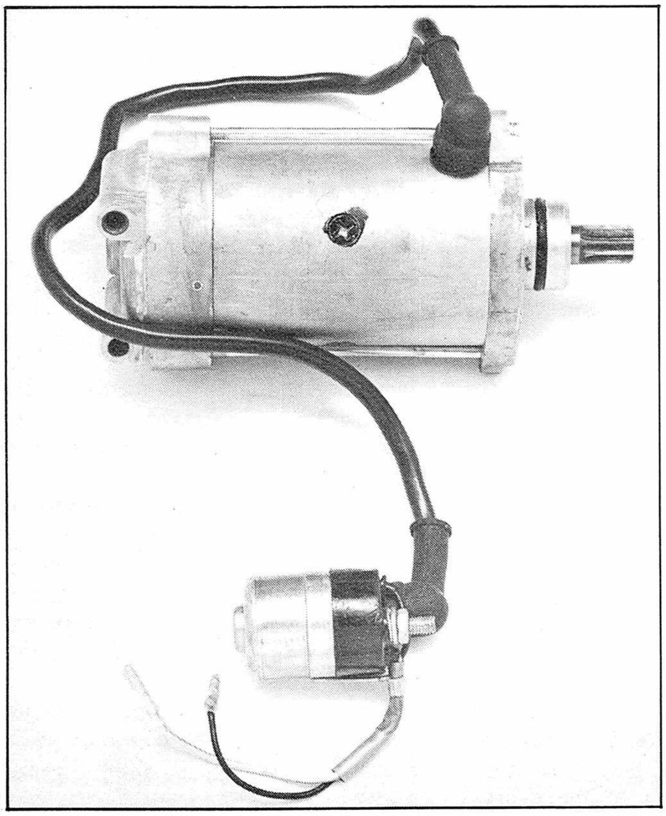
Bultaco has an unusual triggering method to fire the spark plug. Whereas Kawasaki uses a separate little generator to create the current for the SCR, the triggering coil for the Femsa is built into the primary ignition generator. The triggering coil is set to activate the SCR whenever a north pole swings by. Normally, generator magnets are placed so that they are oriented in a north-south-north-south arrangement. But this is impossible on the Femsatronic. There would be a number of sparks on every revolution. Femsa goes around this by setting the magnets into the rotor so that there are four south poles in a row and then a north pole to trigger the spark at the proper moment. Some generating

1. Typical starter motor and solonoid. Starter button on handlebar can't carry electrical load to motor. Solonoid is an extra heavy-duty switch, electrically operated by starter button.

2. High tension coil from Japanese motorcycle using E.T. system. CDI coils are identical in appearance and can sometimes be interchanged from system to system.

3. New Honda XL-250 has an "inside-out" alternator. Coils mount in cover and magnet rotor has open side facing outward. No special puller is necessary to work on coils with this method.

4. Examples of accessory capacitor discharge units. Essentially, they are capacitors using SCR firing mechanisms. Battery provides the trigger current.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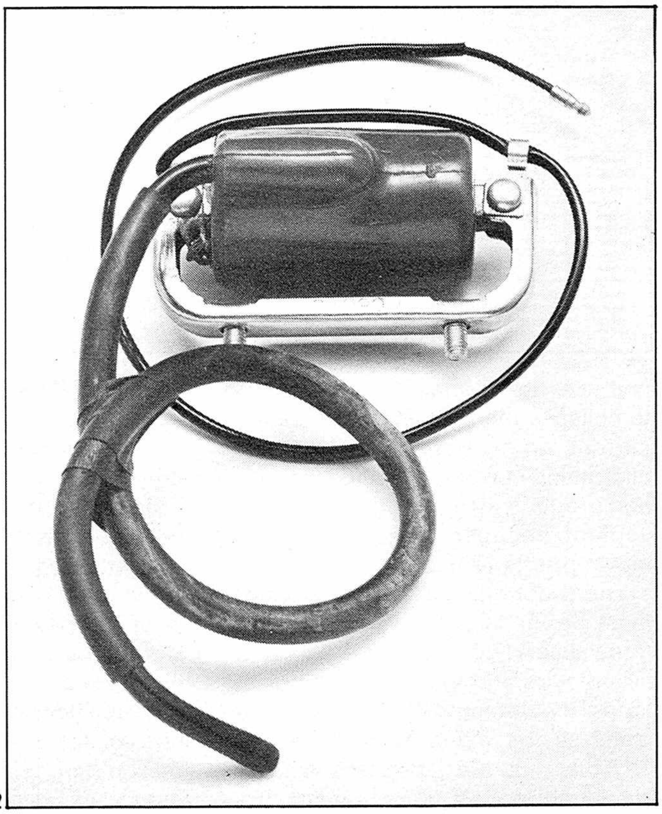
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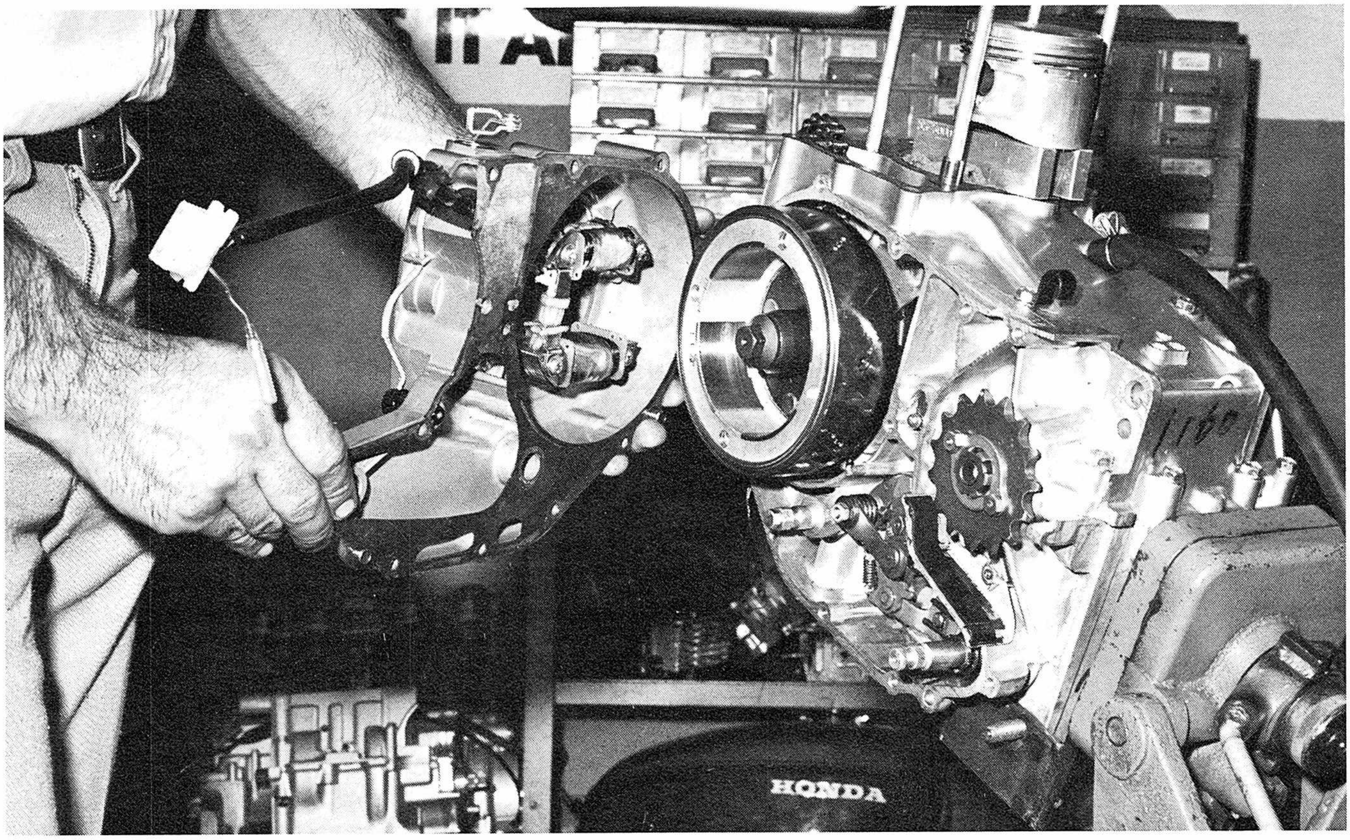

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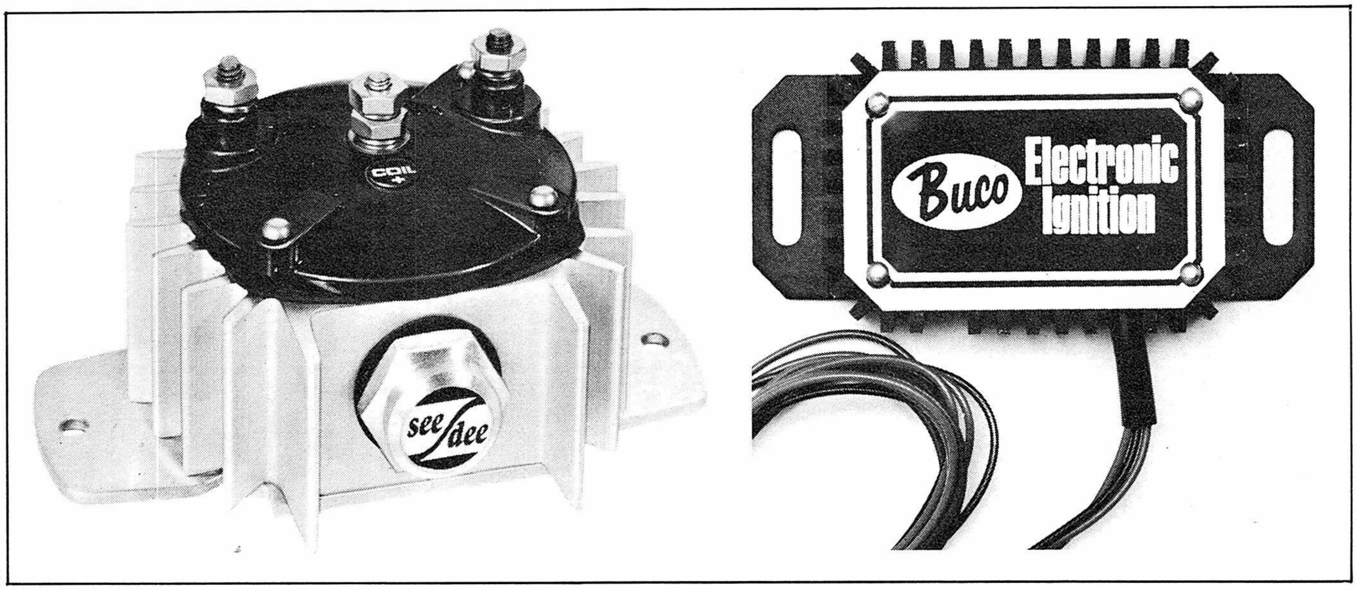

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efficiency is lost but it doesn't seem to hurt or hamper anything.

Lighting is totally separate from the Femsa ignition system but mounted inside the same generator. The entire lighting system can be removed from the machine without getting into the ignition. This is a wise way to make the electrical system because it ensures a consistent ignition. If the lights operated from the same circuit, it would make a difference whether they were on or off. Compensations would have to be designed into the system to make it work under both conditions. Separate circuits prove much simpler in the long run.

Troubleshooting one of these is very straightforward. Look first for broken wires or bad connections. If it's not that, replace the generator or replace the coil. By using a volt-ohm meter, the generator can be tested to see if it's putting out the required current. This will determine which component is faulty and needs replacement.

It is possible to use the Femsa high tension coil with a normal contact breaker and generator hooked into it. This isn't a better way to run an ignition, it's just one of those flukey things that work out. It is a convenient temporary repair in the event that the Femsa generator is faulty and a breaker point set-up is available.

On some bikes, such as the Kawasaki Bighorn 350, the trigger coil for the SCR is a separate coil inside the generator and it too should be checked for output. If it's bad, there would be no trigger signal and no spark, even if all the other components were in good shape. A simple replacement coil would cure that problem. And they all lived happily ever after.

WHEEL SUSPENSION SYSTEMS

Springs, dampers and geometry work together to provide comfort and stability

The only thing between your comfort and safety and the bumps in the road is that arrangement of tubes, shafts, bushings, hydraulic cylinders and springs called the suspension system. The main job of this system is to permit you and the bike to continue in a somewhat straight line with a minimum deviation from trajectory while the wheels conform to the irregularities of the riding surface. When you look at it from this standpoint, rather than the notion that the suspension lets the bike bounce up and down, you can see that the job of controlling wheel motion over a wide variety of heights and spacings of bumps, at different speeds, can be very difficult and sometimes impossible. It is this action that not only provides the comfort in the ride but helps to eliminate or at least reduce the tendency to stray from the intended path and give some degree of stability, therefore contributing to your ultimate safety. For this reason, the maintenance of suspension system components is not a subject to be taken lightly.

CHECK THE BASIC HARDWARE

The primary points of attention are the ones most often overlooked because they continue to perform their functions even under the most adverse conditions. These little-appreciated but tireless workers are often neglected, but without them the most talked about and least understood functional components would be unable to perform their sophisticated tasks. We are of course referring to the bearings and bushings that hold all of the suspension parts together, yet permit and control their movement. When these begin to wear or lose adjustment, the effects are very subtle at the start. But without warning they can cause the bike to display a very shocking loss of stability. When you suddenly begin to think you have a flat tire on a smooth, hard surface but find you don't, or if obstacles like railroad tracks or washboard surfaces send the bike in strange directions, then it's time to give all those points the once over. Actually it's a good practice to do this about twice a year; it only takes a few minutes and could save some hide.

Start with the steering head bearings. Back off on the steering damper if your bike is equipped with one of the friction types, and see if the forks turn freely and smoothly. Next, while standing astride the bike, place a couple of fingers so that you can feel both the frame headstock and the upper triple-clamp or bearing shield. With the front brake locked, gently rock the bike back and forth, and if you detect any lateral movement of the steering head with respect to the frame you're due for either a bearing adjustment or replacement. Now prop the bike up on a stand or stout box to clear the wheels (together or one

at a time), and enlist a friendly extra pair of hands to steady the bike while you shake, rattle and roll. Wheel bearing looseness can be detected by gripping the wheel with the hands diametrically opposed and pushing with one and pulling with the other. A 'clunk' will give the clue. Rear swing arm bushings generally wear to the point that they permit side movement, so just sit on the floor and alternately push and pull on the swing arm while keeping an eye on the point where it attaches to the frame. Worn bushings can be felt and often seen. With the rear wheel clear of the floor, stand over the rear of the bike and reach down and lift the swing arm on both sides just forward of the axle. The tendency should be for the bike to raise off the box immediately, but if the wheel moves up first take a close look at the shock bushings. Front fork slider bushings are checked by facing the front of the bike and giving a tug at the lower end of the sliders simultaneously while the wheel is off the floor. Don't confuse the slop here with that in the steering head if it is loose. Periodic inspection, adjustment and lubrication of these vital suspension components will put your mind in the proper frame for digesting the heavy facts of springs and damping.

First you have to realize that coil springs are weird little guys; cut one in half and it doubles its strength; spread its coils wider diametrically and it becomes weaker; it's enough to put a junior engineer in the bughouse until he lives with it awhile. Of course we won't let that happen because we're going to sneak up on the beasts. Hang in there while we examine the tools, so to speak, that an engineer has at hand when he sets out to build a spring for a given job.

WIRE DIAMETER

All things remaining equal, the larger the wire diameter, the stronger, more resistant the spring. Limitation is determined by the solid, fully compressed height of the coil under load. Wire quality also has bearing on wire diameter; the steeper the wind, the more critical the quality.

WIRE LENGTH

The biggest restriction to coil spring design is that of permissible length. The more working space available, the easier the project. Also, the longer the wire, the less resistance it will offer, a fact more easily visualized if one thinks of the wire in a straight configuration rather than a coil. Of two wires, the longer one will bend first due to increased leverage by the weight bearing against it. Without restriction of length, optimum spring travel can be achieved without coil bind, and the pitch (angle) of the coil can be in many ways most advantageous.

WIRE TYPES

Thickness of the wire and pitch of the coil are governed by the quality of wire; that is, its tensile (end-to-end) strength and resistance to fatigue (elongation and yield points). It is interesting to note that the tensile strength of steel wire has no effect on bending or twisting resistance; however, increased tensile strength does provide greater resistance to fatigue. Tensile, yield and elongation factors provide the chief references to wire.

When a spring works, it develops heat, so this must be considered. Chrome vanadium offers desirable qualities for spring application; it has fair heat resistance but will not stand up to heat as well as chrome silicon. However, chrome vanadium is clean (dirt-free) wire, whereas chrome silicon is more prone to fracture due to its inherent impurities. Cheaper wire, such as one of the cold-drawn carbon types, is more apt to be found in standard suspension systems, oscilations-per-minute being lower, whereas higher quality wire, such as might be found in a custom spring, is naturally better able to withstand the settling or breaking hazards of competition and carries a high priority with the serious or professional rider.

COIL DIAMETER

Providing that the same static height is maintained, increasing a spring's overall outside diameter means that the wire is lengthened and, as previously mentioned, since

1. The advent of grueling moto-cross as motorcycling's most demanding sport has led to new and more severe demands on front and rear suspension. units.

2. Spring wizard Tim Witham gets one of his super coils measured for proper length by editor Bob Greene. Domestic spring betters Hatta fork.

3. A small array of the endless spring design variations for motorcycles from Harley trikes to Ceriani forks to Girling shocks to coils for valves. Choice of quality chrome vanadium steel wire makes vast improvement over high-silicon imported material.

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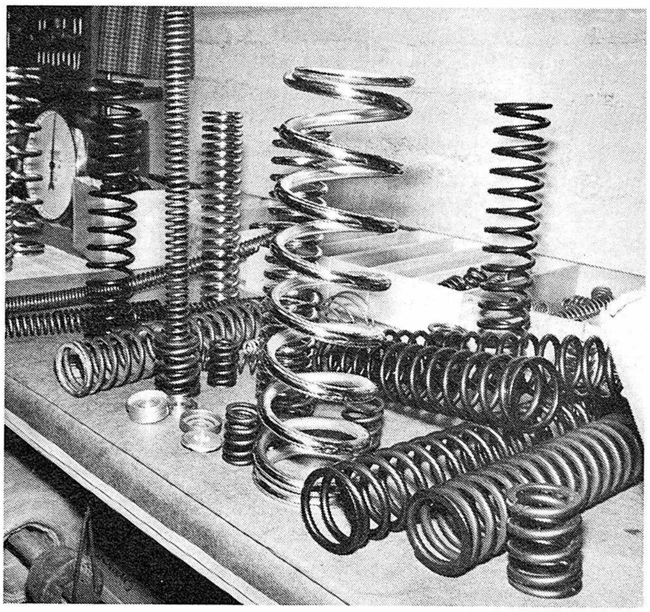

the wire is longer, less pressure is needed to make it flex. So widening the coils from side to side makes for a softer spring. An example of the utilization of coil diameter to advantage might be as follows: In a case where spring height was limited, but coil width relatively unlimited, and the manufacturer was striving for a softer ride, he could increase coil diameter. Another manner of achieving the same result, of course, could be the use of smaller gauge wire, but this might force him into a higher quality wire and therefore more expense, in which case the former technique would probably get the nod.

COIL PITCH

We might call this the angle of the dangle; engineers refer to it as the angle of the working coil, and the steeper that angle becomes, the shorter the wire and the more resistance; the more shallow that angle, the longer the wire and the less resistance. Since the steeper angle creates more resistance, it also imposes more strain on the wire, possibly necessitating tougher quality at added expense.

COIL TYPES

Thank heaven there are only three. The single-rate spring is where it all began; that is one in which all the coils are evenly spaced apart and the spring rate (resistance) remains constant, never changing as it is compressed inch-by-inch. Each coil deflects an equal amount with increasing resistance. For example, a 50-pound-rate spring will compress one inch for the first 50 pounds of pressure put against it, two inches under the next 50 pounds (or a total of 100 pounds), three inches for the next 50 pounds (150 total) and so on. Although the total adds up, the rate never changes: single rate.

Which was all very neat and simple until some wisenheimer invented the two-rate spring, wherein part of the spring is wound with a normal pitch and a usually shorter section at one end is cranked at a more shallow pitch so that two stages of suspension are combined in one spring. As the two-stage spring is compressed, both segments begin to collapse, but the shallow-wound end compresses faster, meaning that initial travel is softer, until the weaker of the two winds becomes coil-bound and the full load is picked up by the higher-rate coils. The theory behind the two-rate spring is that the soft end will handle small road irregularities that would hardly register on the stiffer single-rate spring that would be necessary to cover the full spectrum of impact loads.

Still a third variation on spring winding is the progressive wind, where the pitch of each coil increases slightly from coil to coil, and the action becomes progressively stronger as the spring is compressed. Progressive springs are usually limited to higher frequency applications such as valve springs, where the constantly changing rate is used to damp ad-

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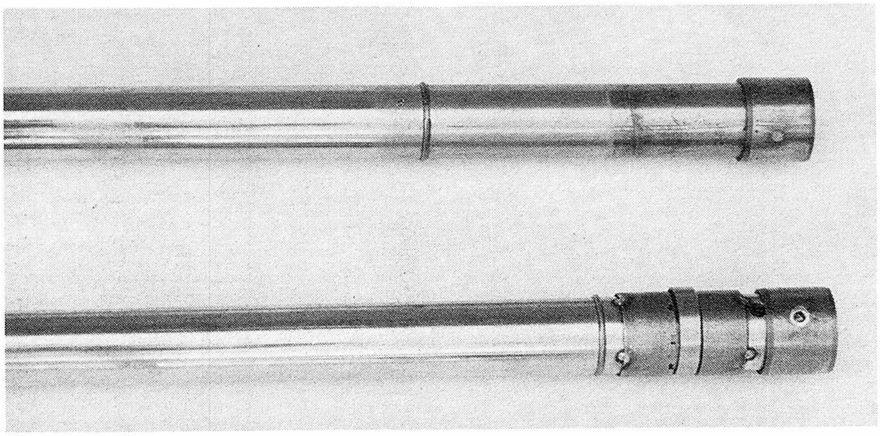
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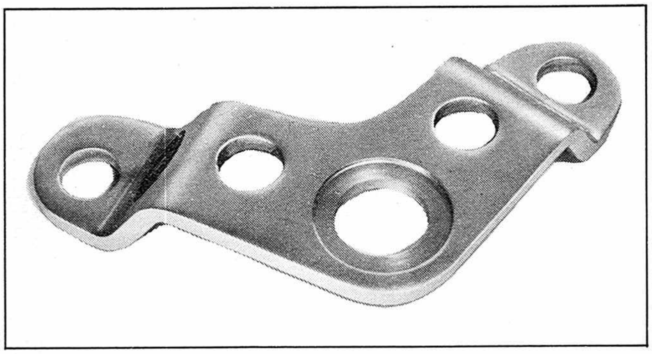
1. More important than people think is the improvement in handling of a road machine when the right type and weight oil combo is found for the front forks. Reduces wiggle, wheel hop and topping.

2. Oil-dampened forks use oil orifices between stanchion tube and lower slider for damping. Not effective in stock form (top), lower tube is modified for more travel and increased oil flow and hydraulic restriction.

3. Rake plate from Circle Industries pulls top of fork tubes back and sets axle out. Increases castor angle.

4. Fork braces are used commonly on Japanese front suspension units. Victor Products designs theirs to bolt to upper sliders. Claim is increased rigidity.

5. Another common problem with Oriental suspension units is fork springs collapsing prematurely. These booster springs take up the "slack" of springs.



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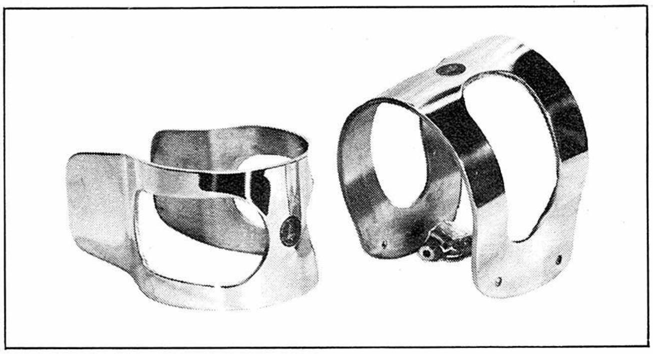

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verse harmonics. In a motorcycle suspension unit the hydraulic shock absorber normally handles the required damping. Where progressive springs are used, however, the progressive (softer) end of the spring should be mounted away from (opposite to) the point of impact. Generally speaking, a lighter machine would benefit more from a progressive spring.

Although it is the most important feature of suspension systems, damping is probably the least understood. There are two basic types of damping used in today's telescopic forks. Both are hydraulic and both have a mechanical method of controlling the oil flow rate in the fork tubes. The first type of damping is called "oil damping." The second type is referred to as the "double dampened" system.

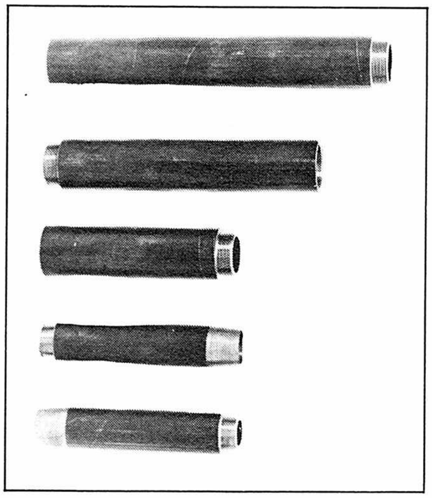
The "oil dampened" forks have only 10 percent or so of the hydraulic restriction on the downward stroke as the main stanchion tube enters the lower fork leg. The remaining 90 percent is on the rebound (upward) stroke. Thus most of the downward (compression) restriction is achieved by the rebound action of the springs. The oil damping comes into play on the upward stroke and in theory restricts the spring rebound at an equal rate.

The oil damping system's design and construction is relatively simple. The only damping restriction to the downward action of the forks is supplied by the oil passing up through the main stanchion tube as it is compressed into the lower leg. The main damping action comes in when the spring pushes the stanchion tube away from the lower leg and the oil which has been forced into the small area between the tube and lower fork leg is expelled through a series of orifices (small diameter holes). Since 90 percent of the hydraulic action is on the rebound stroke, forks of this type are not really suitable for serious thrashing in the boondocks. However, they are certainly adequate for street and trail riding.

The second basic type of damping for hydraulic forks is called the "double dampened" system. This system is certainly not new, but was formerly considered too expensive for production use. Ceriani and the manufacturers who adopted their forks changed this concept. Fierce competition decreed that manufacturers adopt the Ceriani double damping-type forks or perish in the market place.

Double dampened hydraulic forks dampen both the downward (compression) stroke and the upward (rebound) stroke, doing about 30 percent of their dampening on the downward stroke and about 70 percent on the upward stroke. The exact percentages vary slightly from unit to unit, because each fork unit is designed to be compatible with a certain spring rate, a certain size and type of motorcycle. If a machine employs a strong straight-wound spring, it would work best with forks that have more damping on the upward stroke; a bike with a light progressive-wound spring would work best with forks that have more damping on the downward stroke.

There are many variations in the specific internal designs of Ceriani-type double damping systems (to match the many types of motorcycles), but basically the forks contain an assembly to control the flow rate of the oil which consists of a complex-appearing system of washers and other restrictive devices. Usually the washers with a series of orifice holes move on the main damper rod, permitting them to open or close the orifices to



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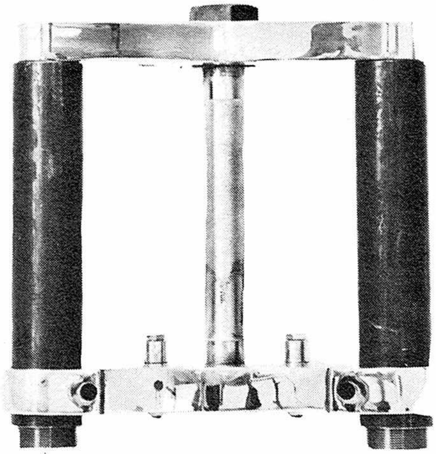

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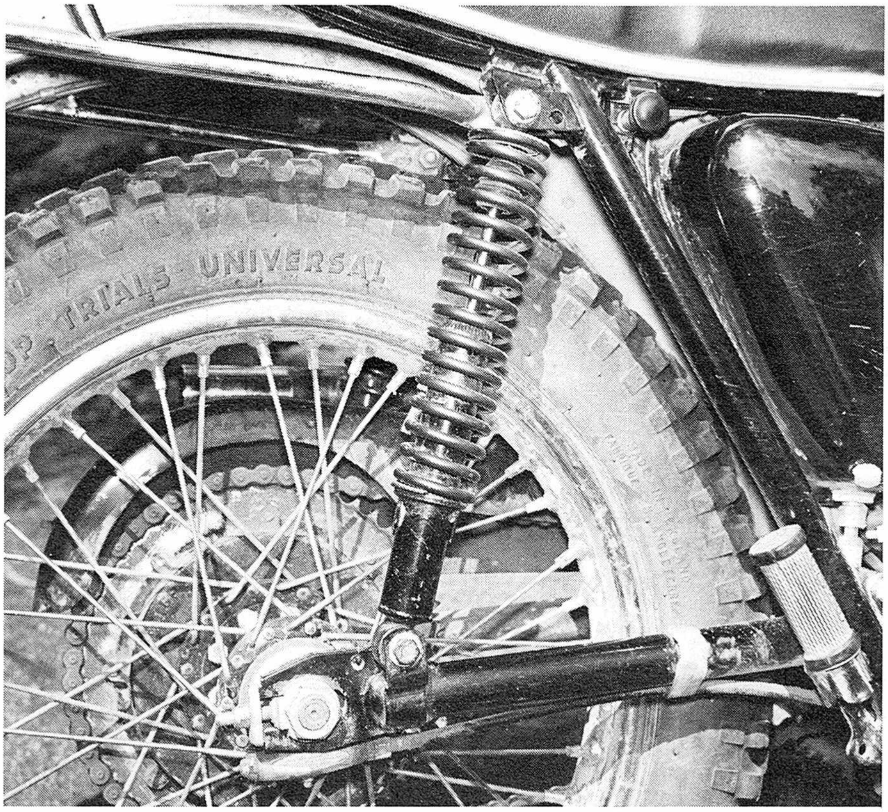

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the flow of oil, depending on whether the fork is compressing or extending.

Some external-spring forks also have a double damping system as do the Ceriani types, and all double damping forks are complex assemblies. Washers, springs and orificing devices are constantly moving inside the fork tube to control the damping as the bike is ridden. Friction and heat are produced, so the parts will wear. The oil will eventually get dirty, break down and foam.

Most motorcycle owners seldom change the oil in the forks (the exception being competition riders), and this results in prematurely worn or ruined forks. Double damping forks are particularly susceptible because of their many moving parts. Perhaps half the Ceriani type fork-equipped machines have excessively worn front forks due to lack of maintenance.

Excessive wear of the stanchion tube and lower leg will cause the forks to wobble. This wobble may seem very slight as you ride, but it causes highly accelerated wear on the fork tube's finish and the bushings in the lower leg, leading to friction, excessive heat and oil contamination by shavings . . . a vicious circle.

The slightest wobble can also put a side load on the damping assembly, resulting in more friction, more contaminants. . . .

Bad seals are another cause of ruined forks. When the seals go bad, they not only permit oil to leak out, but they permit the environment to come in. Dust, dirt and moisture cause wear, rust and corrosion. So replace the seals immediately if you notice they've started to leak.

Scoring marks running up and down the stanchion tube are evidence that the seals went bad some time ago; they are caused by dirt buildup on the seals and bushings. Once scoring has started, the forks will always leak, and as the stanchion tubes are flash chrome plated, the scoring is irreparable. You'll need a new set of stanchion tubes, and if the double damping assembly has been damaged, a whole new set of forks will be needed.

FORK OIL

Regular oil changes will insure long life of a clean operating set of forks, especially if you ride in dust or water. It is important to change the oil frequently, and equally important to use the right oil. For the average road machine, the 30-weight motor oil recommended by the manufacturers will suffice, changed every other month or so. (If the old oil comes out very dirty or full of foreign particles, it would be a good idea to change it once a week until it clears.)

You should change the fork oil once a month or more often if you do any off-road riding with oil-dampened forks, and use a heavier (40 or 50 weight) oil to improve the damping action. The 50-weight oil is commonly used in warmer areas to offset the combination of higher atmospheric and operating temperatures.

Most double damping forks have close tolerances and high-grade metals, with most area of friction involving steel on aluminum or bronze (bushings). These metals live together relatively well if bathed in oil. The trick is choosing the right oil. Ceriani forks are designed to work best with hydraulic fluid, and this is the ideal oil to use in any suspension unit because it will not foam. It maintains an equal viscosity when subjected to temperature changes, and it contains special additives that keep rubber seals in condition. The only trouble with hydraulic fluid is it is hard to come by. About the only places that carry it are companies dealing with hydraulic machinery (fork lifts, ma-

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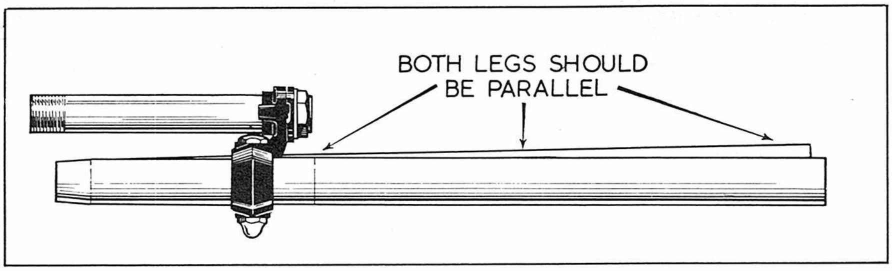

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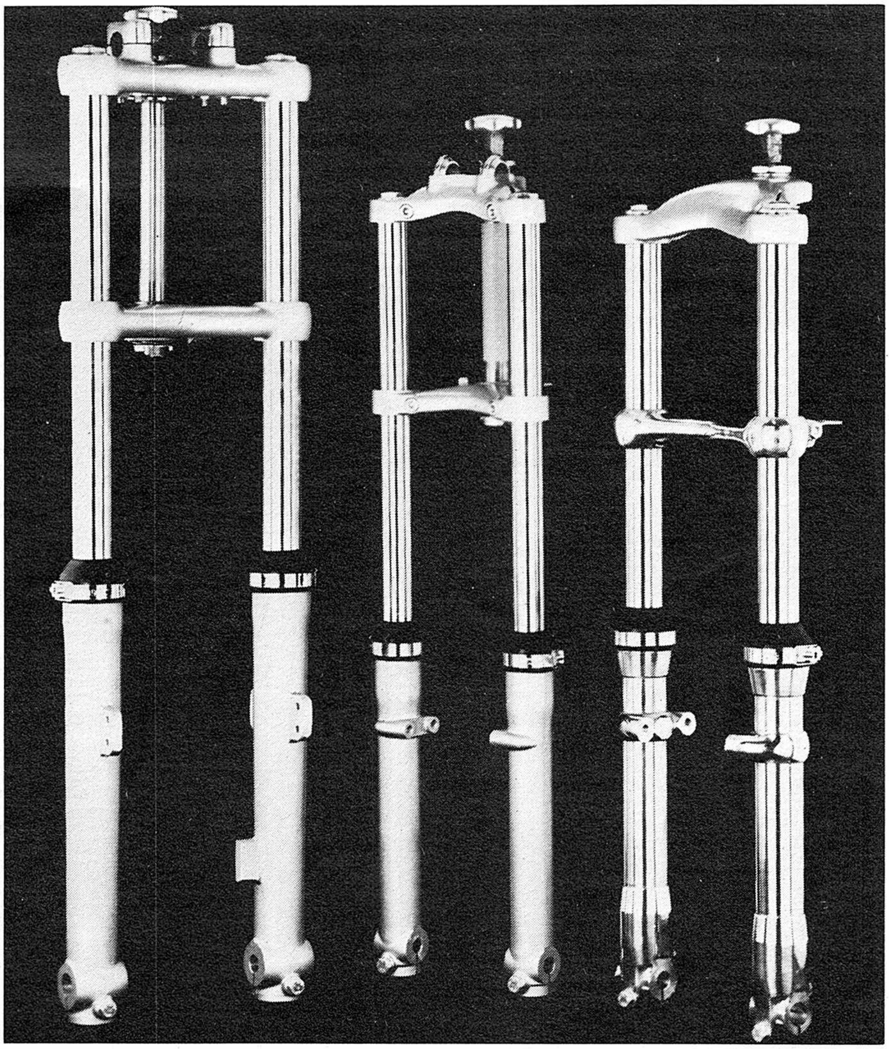


chine shops, etc.). However, automatic transmission fluid, readily available at your local gas station and relatively inexpensive, has the same good qualities as hydraulic fluid.

The excessive friction and wear on the moving parts of front forks can be alleviated only by regular oil changes and using the right oil. The best way to find out which is the best oil for your forks is to start out with a thin oil, like automatic transmission fluid, and see how it works. If the forks don't dampen well, or bottom or top out, try using a 10- or 20-weight oil, and if this won't do the job, try a 30-weight oil. If this won't do the job, something may be wrong, like worn or broken damper assembly parts.

TIRED SPRINGS

Springs present another problem with suspension units. The condition of the fork springs will definitely affect the damping rate. Japanese fork springs often "sack out" or collapse and lose their rebound ability in a short time, so that the forks settle down more and more as miles are put on the motorcycle. This is true not only of off-road machines, but also of heavier road bikes like the Kawasaki Mach III. This problem has two solutions: Adding a short booster spring to pre-load the stock spring, or replacing the stock item with an American-made accessory model or obtain one from a pair of Cerianis or other European forks with the same size spring.

To check the condition of telescopic forks, stand over the bike, grab the hand grips and push the forks down as hard and as fast as you can. The forks should depress about one-half to two-thirds of their available travel if the spring rate is about right for your weight; if the forks compress completely to the bottom, chances are the spring rate is too soft for you (or the springs are shot). If the forks will not go down further than one-fourth of their travel, the spring rate is probably too stiff. (Exceptions to this would be trials machines, which have very soft springs, and some motocross bikes, which have relatively rigid fork tension.)

While checking the spring rates, you should try the dampening system. As the forks reach the bottom of their travel, let them return without putting any weight on the handlebars. If they return rapidly, the oil is too thin, there is too little of it, the damping units are worn, and/or the system is an oil damping and not a double damping system. If they're new forks, check with the dealer and find out if the damping rate is normal, and if not, what will he do to correct it. If the damping system is working correctly, the handlebars should rebound at about two-thirds the speed at which they can be compressed.

That done, ride the bike and see if the forks are giving you the ride you want. If you're looking at a new bike, also ride a demo or used (but not too used) example for comparison, as brand-new forks may be a little too stiff for you to make a fair appraisal of their performance. Pick up speed and then

1. Current craze in customizing bikes is longer "extended" forks. Stretching out forks is often accomplished by extending length with "slugs."

2. These seven-inch "slugs" have female threads at top, fork tubes screw onto bottom. Because of the drastic loss in strength, extending forks with slugs is not desirable.

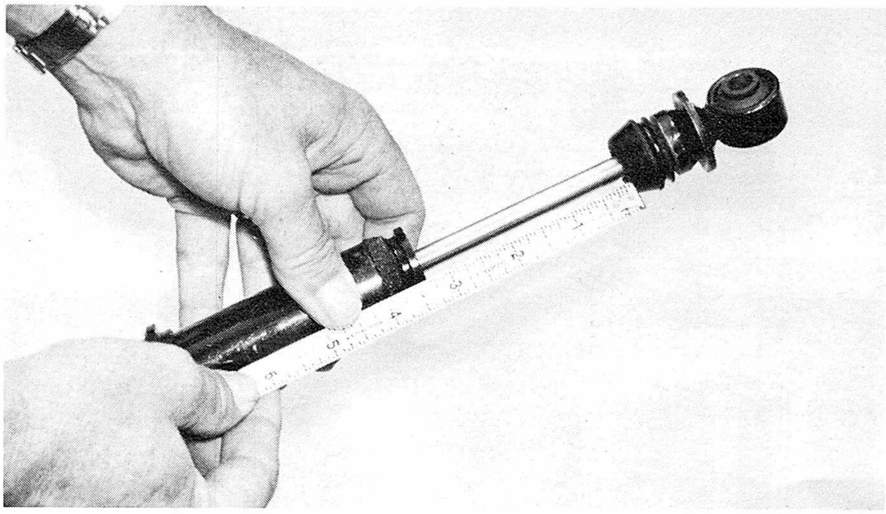
3. Many variations of spring and shock combos are available to meet any situation. Triumph dirt digger used four-inch-travel Girling dampers from Norton with 90-pound S & S springs. More travel for heavy rider, bike.

4. Just a strenuous twist or tweak can bend one or both fork legs. With the wheel and slider off, parallelism of stanchion tubes can be checked.

5. Ceriani forks have been the standard of superior forks for years. Superior damping and springs featured.

brake rapidly. If the forks compress completely to the bottom, they are lacking in either spring strength or travel, causing too much weight transfer to the front end, which is not desirable. Under hard braking, the front forks should compress no more than three-quarters of their travel (excepting locked-up panic stops).

The forks should not make any noises, banging, chatter, or bounce in an uncontrollable up-and-down action. Any of these indicate bad damping and/or worn or improper oil, and you should make sure the dealer can cure them before buying.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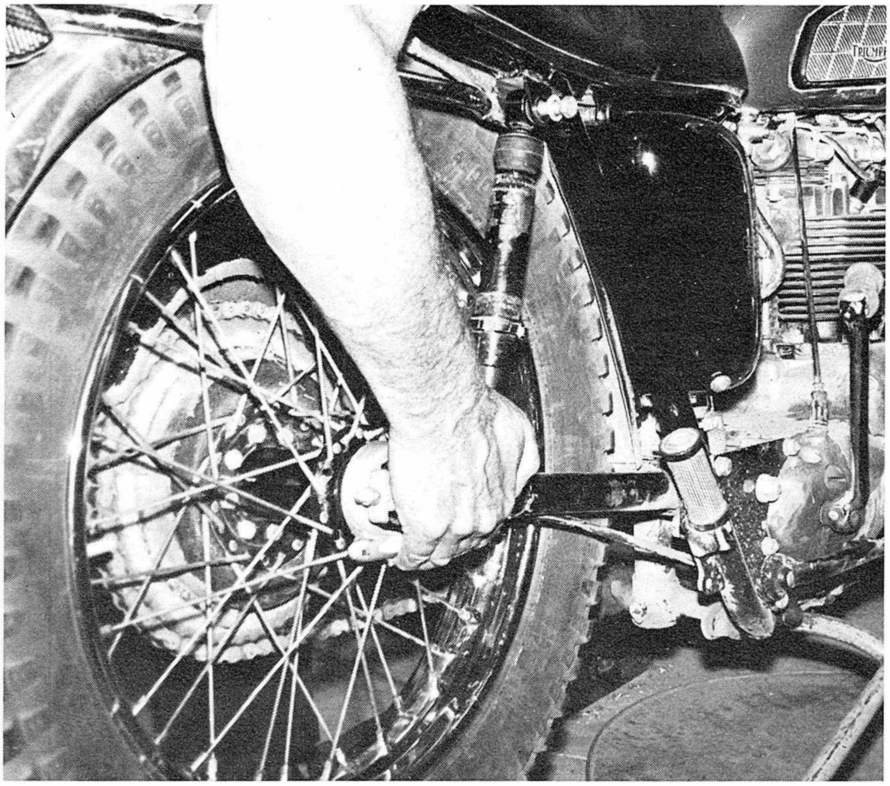
REAR SUSPENSION

Over the years, the swinging arm and spring-over-shock absorber combination which became the standard rear suspension on all production motorcycles more than a decade ago, has proven itself to be the best performing and most practical type of rear suspension system.

The rear fork is an arm that swings (hence the name swinging arm) or pivots to allow the rear wheel to go up and down, providing cushion and stability. The swinging action is controlled by the rear spring-over-shock absorber units, which provide controlled restriction for the downward pressure of the motorcycle (or upward travel of the wheel). If there were no shock absorbing action, the rebound of the spring would tend to shoot the back of the machine (and rider) up like a slingshot.

The Europeans, with years of experience, produce good rear shock units. The Japanese have progressed more in the area of good front fork units than with rear shocks.



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1. Before installing longer shocks, measure their potential maximum travel. Most shocks have 2¾ to 3¼ inches travel. Long Girlings and Konis can have up to four inches of travel.

2. Remove old shocks and install new dampers without springs. Raise the rear wheel until damper is fully compressed. Place block under axle.

3. Spin the wheel and listen for abrasion or tire drag noise. If you hear noise, look for shiny spot under fender. This means higher fender or shorter shocks. If you contemplate new tires or knobbies add at least ½-inch additional clearance.

4. Most novel rear suspension system is used on homemade mini-bike. Cast swing arm pivots on jackshaft and has shock spring mounted in upper horizontal position for leverage. Spring travel is about ⅔ of swing arm.

THE SPRING

Whereas Japanese springs on front forks often tend to sack out, the reverse situation is true of their springs for rear shocks. These are usually too stiff. Most European shocks have available interchangeable springs of various strengths, and it is relatively easy to install a spring to match your weight, machine and riding conditions; this is not the case with Japanese units unless a special American-made spring is available.

The damper units on most Japanese production shocks leave a lot to be desired as well, and unless you have one of the few Japanese shocks that can be disassembled, you can't do anything about it. The basic construction of Japanese damper units is similar to that of European units, involving a plunger that slides up and down in a separate sleeve in a sealed oil bath.

THE DAMPER

Damper units offer little restriction on the downstroke (as the spring compresses), with most of the damping action taking place on the upstroke (as the spring rebounds) to control the rebound of the spring. The Japanese units differ from the European units in the design of the damper orificing (oil flow control), size of the parts and grade of oil or fluid used.

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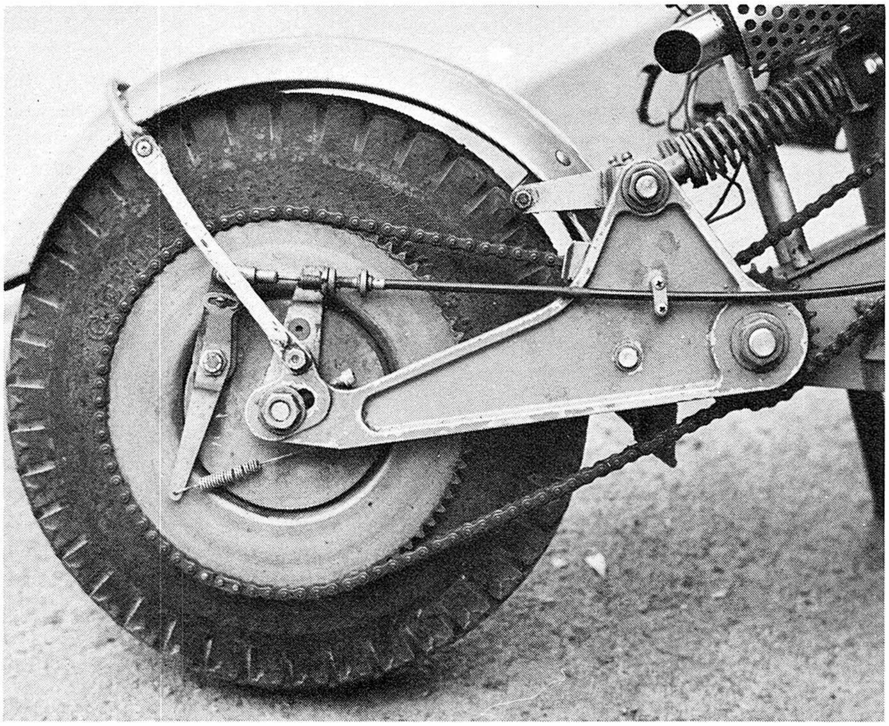


Oil flow orificing in the Japanese units is just not up to the task of overcoming the strength of the generally stiff springs, and the rebound of the spring action is much more than the damping action of the shock absorber. The poor fish oils used by the Japanese units are apparently just not up to the task of providing an adequate damping fluid in the shock absorbers, and they break down quickly when subjected to operating heat and friction. If you have one of those few Japanese units that can be disassembled, change the oil to automatic transmission fluid and install a better spring.

Most Japanese shock units are smaller (especially in diameter) than European units, leading to premature bending of the main shaft and resultant damage to the rest of the unit. Excessive bottoming of the unit due to poor damping or spills or blows to the side of the unit can cause this. If the main shaft is bent even 1/64-inch the whole unit is useless. It's not uncommon to see a shock lock-up permanently due to a bent shaft, resulting not only in a ruined shock but very often bending of the swing arm.

One result of using these poorly-designed Japanese rear shock units is bad handling characteristics of the motorcycle. The street rider experiences a stiff ride and excessive weight transfer to the front wheel when decelerating or braking, due to the strong shock springs pushing the back upward, and overpowering the poor damping. This results in too little weight on the rear wheel for braking traction, and overloads the front brake and tire. The off-road and competition rider finds the back end wanting to hop around excessively with an obvious loss of traction at the rear wheel, plus a tendency of the rear shocks to push the machine and rider up very quickly on the rebound action.

PRE-LOAD:

Having previously discussed spring rate, or the manner in which spring tension is measured, we find that there is a way to fudge a bit if things don't break quite the way we would like. A 50-pound single-rate spring picks up 50 pounds of resistance for each inch it is compressed; a 100-pound-rate spring gains 100 pounds for each inch of compression, etc. But supposing that a 100-pound spring is too stiff for our particular need, especially as it reaches the final stage of compression before bottoming out on the built-in rubber snubber in the shock absorber. We suspect that we would be better off with a lighter spring, and yet we fear that to do so would allow the chassis to "sack" an inch or so with the rider at rest in the saddle—not so good because we would be losing that inch of initial travel that we so dearly need.

The answer lies in a perfectly legitimate gimmick known as "pre-loading." Let's try that 50-pound spring, but let's find one that's an inch or so longer than the extended length of the shock absorber and compress it so that the top shock keepers hold it in a compressed—or pre-loaded—posi- after assembly. Thus, if the 50-pound spring is run with a one-inch pre-load, that means it has a 50-pound tension at rest, without the rider seated. With the rider aboard and in action, the first inch of depression brings the 50-pound spring to 100 pounds (50 pounds pre-load plus one inch of compression). The second inch of travel it picks up another 50 pounds (50 plus 50 plus 50) for a total of 150 pounds with two inches of depression. Three inches depression: 200 pounds.

How would that compare with the previously considered 100-pound-rate-spring without pre-load? Momentarily discounting the weight of the motorcycle for simplification of this example, the 100-pound spring would

stand tall unladen, without a pre-load. For the first inch of depression it would pick up 100 pounds of tension, the same as our 50-pounder with a one-inch pre-load. But the second inch would bring it up to 200 pounds tension, and the third inch would result in a more explosive 300 pounds tension (100 plus 100 plus 100), a full 100 pounds more than our 50-pound spring that gave us 200 pounds at the same three-inch depression. And so, by pre-loading the lighter spring the necessary amount, we can have a sack-proof extended condition exactly the same same as a stronger stock spring, plus a softer travel throughout the range as it is depressed. Of course these poundage examples are for illustrative purposes only and your particular ideal situation will understandably lie somewhere in between. Your bike probably has a three-way adjuster on the shock; that's pre-load. Play around with it and you'll undoubtedly see this principle in action.

Which brings up the logical question: "How strong should a spring be?" Well, many "shoes" are of the opinion that a spring/shock combo is pretty close to right-on when it just lightly kisses the stop maybe two or three times a day, when you connect with that occasional ditch you didn't plan to hit at all. At least you know you're getting full travel. We suspect that most riders have a tendency to run too stiff a setup front and rear. At the rear, the shock absorber provides minor restriction (10 to 20 percent) on recoil but slows down compressed spring energy on counter-recoil (snap-back) by 80 to 90 percent. Up front, the situation is somewhat reversed, with hydraulic damping handling a greater share of the recoil than the shock absorber.

CUT TO THE GARAGE

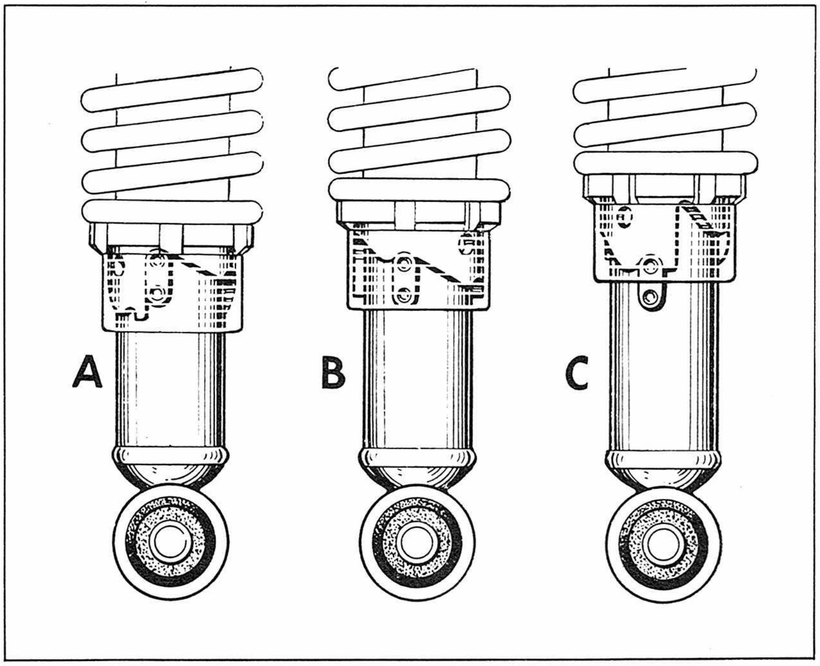
OK, let's see if we can put all this gobbledygook to work in our backyard scooter improvement plan. First let's investigate those rear shocks: Stand over the back of the bike and shove down with all your weight, then release your weight suddenly and notice how the rear of the bike reacts. If it jumps up instantly, suspect that the shocks are ready for retirement, but if it comes up nice and easy, you're in business.

But if your tail is still tingling from that last ditch, when that two-wheeled bronc just about spit you over the bars, and you gotta find out why, stick around; that's what this gig is really all about. Just sorting out the possibilities can be a mind-blower: Was the rear spring too stiff, making you a human projectile in a spring-loaded popgun? Or did the tire bottom-out on the fender or fender bolts long before either spring or shock had fully compressed?

Whatever the cause, the approach to the solution of a rear suspension problem is this simple drill. Put that baby up in the air by blocking it up on a box, then pull off both rear shocks, easing the wheel down to the floor as the last one is removed. Now lock the bottom eye of one of the shocks in a vise and compress the spring with one hand while removing the half-circle spring keepers from the top with the other hand. If you're feeling sickly, better have your mother-in-law remove the keepers while you fight the spring.

While the shocks are off, and relieved of their springs, check their valving by hand, pulling each one out and forcing it back to determine if one is noticeably weaker than the other. It has been known that a motorcycle manufacturer would fit two shocks of a different series on the same machine, which would, of course, have a tendency to cock the swing arm upon impact. If one feels appreciably weaker than the other, or if the serial code numbers on the reservoir body are different, the replacement of at least one is in order. Convinced that the plunger shafts are not bent or galled, and that the units are matched and in good order, we're ready to continue our search.

Remount one of the shocks back on the machine, minus the spring, so that full wheel travel can be checked with ease. Raising the wheel into the fender well, observe whether or not the tire is clearing the sides of the fender as it goes in. If it is fouling the fender, bump the sheetmetal out until it clears. Then straddle the back of the bike from the rear and pull the wheel as high as it will go; ideally it should be able to turn free, without the tire rubbing the fender or its attachment bolts. As a final check, lift



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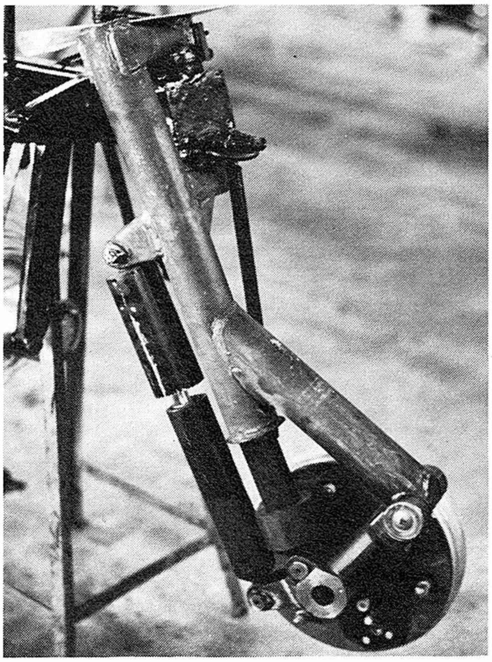

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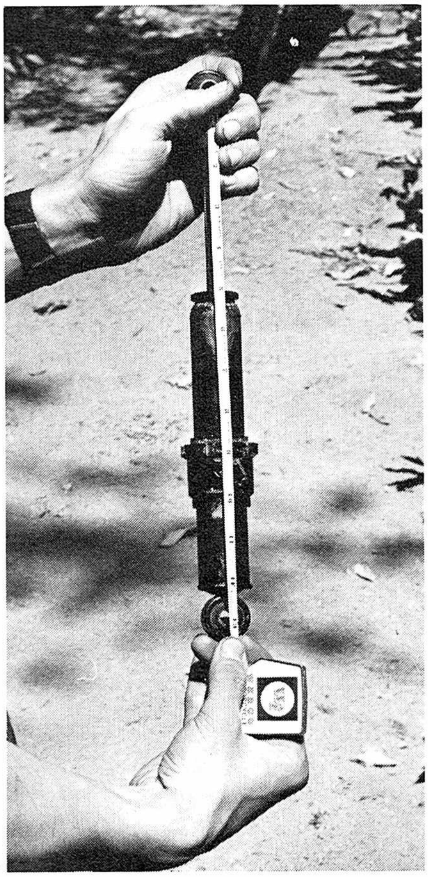

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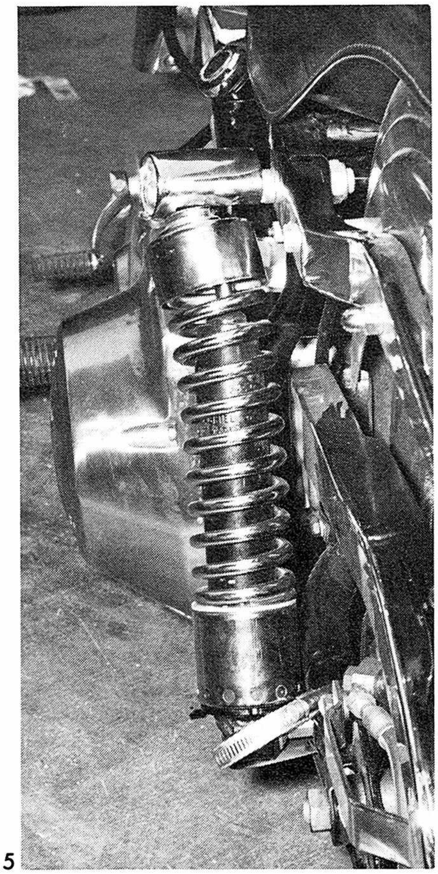

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1. Most all shocks have cam drum adjustment for spring tension. Raising adjuster increases spring preload. Bottom position for solo riding, middle for two-up and top for hard service and extra equipment load.

2. Unusual concept for Earles-type fork is position of shock behind forward pivot point. Yamaha special.

3. Sachs/DKW leading-link fork is still in mass production. Unique suspension system gives super-smooth ride in the rough.

4. If replacing only one shock or damper unit, it's critical that center-to-center-length of eyes be exactly the same for replacement unit. Pair must also have matching identification numbers.

5. An expensive accident. This big Harley fell on its side, broke damper shaft from force of 800 pounds.

the motorcycle off the box and, stretching out over the rear fender to place maximum weight over the rear end, push the bike along; it should roll free with the shock deeply imbedded in its rubber snubber. If the tire appears to be snagging the fender bolts, substitute some flat-headed carriage bolts. If it shows evidence of bottoming on the fender proper, you'll have to raise the fender.

LEADING LINK SUSPENSION

Among the modern-day suspension systems employed on motorcycles, the Earle's-type front fork, or "leading link" suspension, is about the oldest.

The leading-link front fork is not related to conventional telescopic front forks, but is akin to rear swing-arm and spring-over-shock forks; shock absorption and front wheel travel work through a pivot system rather than the direct up-and-down system of telescopic forks.

Leading-link front ends provide more cushion for bike and rider over rough ground. The pivoting action tends to crawl or roll over objects on impact because the wheel is allowed to swing up over objects rather than take a direct upward shock as with telescopic forks. Also, telescopic forks absorb the rearward force of striking an object by driving upward, while the leading-link system pivots and swings up over the object instead. All of this means leading-link forks absorb more shock than telescopic units.

Leading-link forks are not generally accepted by the American consumer because of their different appearance—they don't look like "normal" telescopic forks—but they may well become standard equipment on many trail and street/dirt bikes as time goes by.

Maintaining leading-link forks is easy because they contain so few moving parts. Just check the conventional spring-over-shock units and the tightness of the pivot bolts occasionally. Make sure the springs aren't collapsed or bent, and that the shock units maintain dampening efficiency. If either of these units needs replacing, replace both to prevent damage to the swing arm of the leading-link assembly.

Leading-link forks restrict compression of the front end during braking. The front brake's backing plate is attached to the swing arm of the fork, and therefore moves with it, and so will allow the fork to compress (if attached to the front of the bottom shock mount) or extend (if attached to the rear of the bottom shock mount) by forcing a pivoting action on the arm. This works well to prevent diving when stopping or going downhill, but takes some getting accus-
if you're used to telescopic shocks.
tomed to if you're used to telescopic shocks.

A good ride under all conditions of road, speed and payload is your indication that everything is working properly under you. The less you feel of the riding surface or strange deviating forces, the more you can concentrate on where you're going and enjoying the scenery. So keep that suspension system in tune, it's just as important as the engine or brakes.

WHEELS

Gather 'round and we'll discuss steel vs. alloy, mags vs. wires and show you how to straighten and lace your own

BY ROBERT SCHLEICHER

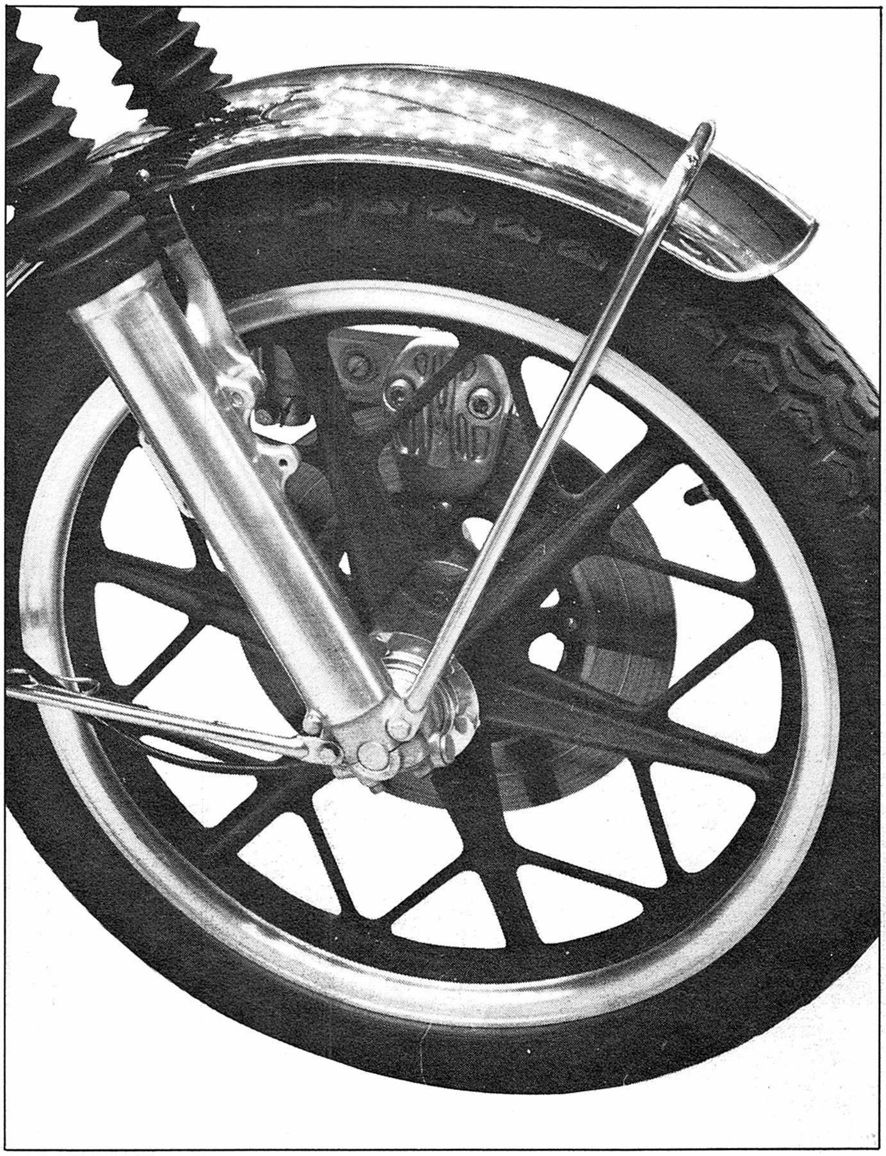
Motorcyclists often consider their machine's wheels as simply something to straighten when bent or, at best, a devilish contrivance to clean. So true, but we are also lucky enough to live in an unparalleled age when a wheel is more than just a means of keeping our hubs from dragging the ground. Oh, they're still round alright, but a fast run through one of the more voluminous accessory catalogs will amaze you with their variety of sizes, metals, cross-sections and styles; tall ones for moto-cross, short ones for choppers, fat ones for off-road and even mags for the cafe racers.

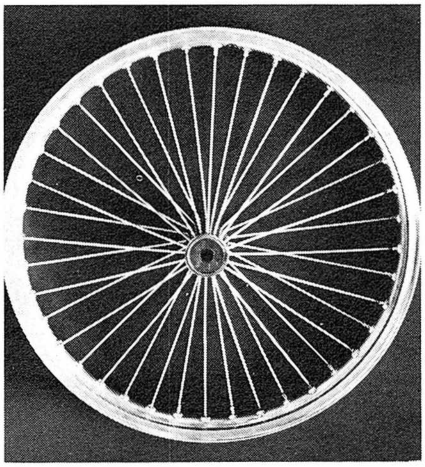
And it's not all aesthetic. Considerable change in steering geometry, handling, braking and comfort can often be achieved once the motorcycle is dedicated to a given task, which can vary from that envisioned by the manufacturer. For he must embrace all eventualities in his original specifications, and build accordingly.

The wheel is merely there to support the tire while it transfers power and braking force to the ground. The problem is that the ground has all sorts of ideas of its own that it tries to transfer back into the motorcycle; things like chuck holes, bumps and enough traction to literally bend the wheel and tire when too much cornering, braking or accelerating force is being forced upon it through that tire. The better brands of front forks and rear springs and shock absorbers do a fine job of soaking up the jolts and gravity loads in such a measured way that the rider has plenty of time to make any steering or body english corrections needed to maintain full control of the motorcycle. For the moment we'll assume you have the very best frame, forks and shocks that money can buy. We'll also assume that you've picked just the right tire size and tread pattern for your specialty of street, highway, drag racing, road racing or off-road use. Now we can blame every handling and control problem remaining on the wheels.

Stop and think about it and you will conclude that the weight of the motorcycle hangs from the spokes at the top of the wheel at any given position rather than being supported by those on the bottom, for although they have great tensile (end-to-end pull) strength, they would immediately bend if even a small portion of the weight of the machine were to be borne by those spokes at the bottom of the wheel. In compression they are relatively weak. And because the wheel rotates when it works, and the forces that are put through it are of a twisting nature, the spokes are angled out from hub to rim in both directions to resist acceleration and braking, approximating a double triangular configuration for maximum strength.

In addition, since the spokes attach to either side of the hub and the center of the rim, another triangulation is formed by the spokes between the extremities of the hub and the center of the rim to resist side loads, which are admittedly much less than those encountered in an automobile because the motorcycle is a single-track vehicle which must bank to corner. The only exception to this arises when a sidecar is attached to the motorcycle, in effect making it subject to the same side-loads as encountered in an automobile. How surprised is the novice operator of a sidecar, either on the street or in





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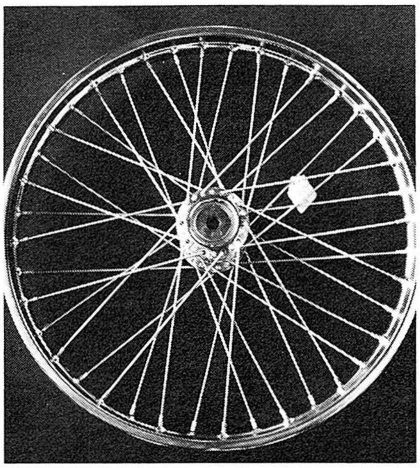

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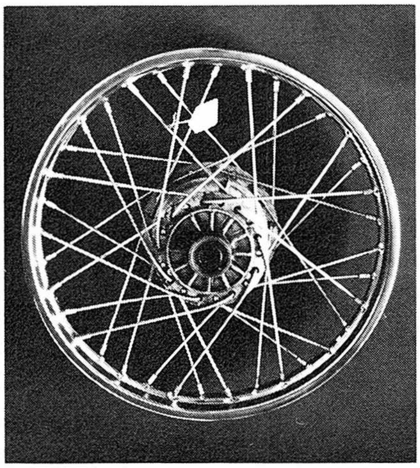

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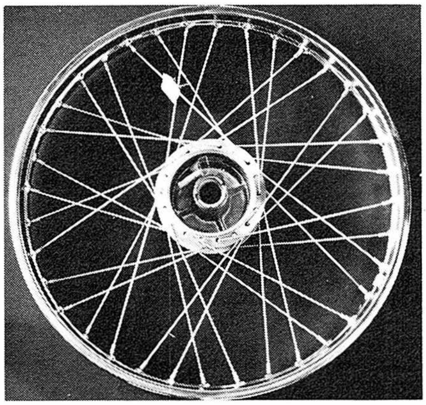

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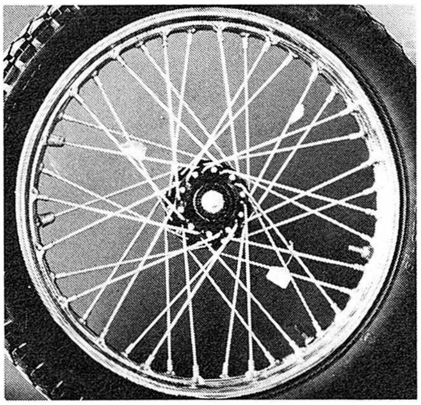

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1. Understanding various spoke lacing patterns is critical to the selection of proper wheel assemblies. Show bikes rarely used on the road can utilize appealing esthetics of straight pull spokes with no crossing pattern at all. Spokes with high tensile strength and should be installed by an expert. Buchanan's spool hub is shown laced to 21" rim.

2. 'Cross three' pattern is strong enough for drag bikes or flattrackers lacking a front brake. Cross patterns (0, 1, 2, 3, or 4) refer to the number of spokes crossed by another (counting only the spokes on the same side of the hub) between the hub and rim. This cross three pattern of Buchanan has the first cross hidden by the wheel hub flange.

3. Strongest for rim support and even transmission of torque and braking loads through the hub is 'cross four' pattern. First two crosses are hidden but can be found with study. Yamaha DT-1 wheel now has No. 8 spokes.

4. Fitting a larger rim front is one of the common wheel modifications. Here a Kawasaki 100 gets a 21-inch rim with a cross four pattern. Hub diameter and spoke hole location can dictate lacing pattern. Check these out before buying a gob of spokes.

5. Triumph wheel has new No. 8 gage spokes in 'cross three' pattern. After rim is trued, tire should be mounted and shaved and then the assembly should be balanced. Clamp-on lead weights (left) offset the extra ounces of the valve stem and tire lock. Many handling quirks are blamed on lack of wheel care such as lack of high-speed balancing.

competition, to find that after a long, hard ride, he is informed by a loud creaking and squeaking that all of the spokes in his rig have loosened and are in drastic need of adjustment.

The spoke lacing pattern, when viewed from the side of the machine, can have a marked affect on the strength of the wheel and its hub. If you have *no* front brake and, therefore, no brake torque loads on the spokes, you can get away with a lacing design where the spokes angle straight out from the hub to the rim so they never cross one another—the wheel experts call this a "cross zero" lacing pattern.

The other extreme of wheel loading arises when the motorcycle is used in rough off-road competition where braking and accelerating torque are often most violent as the wheel hops through the air and bangs into rocks and ruts at full braking or accelerating power. These severe jars really do their best to wrench the spokes right out of the hub. There are few desert racers, for example, who haven't experienced at least one case of hub failure where the spokes have actually ripped the hub apart. The best lacing pattern for this type of use (or abuse) is to lace the spokes so there is as much of a spoke angle as possible between the hub and the rim. The greater the angle, the more spokes a single spoke will corss over. This results in what is rightly called a "cross three' or "cross four" spoke pattern. Even the best of the ready-to-race off-road machines don't have a spoke pattern where each spoke crosses over four others between the hub and the rim; an expert wheel man (maybe you, if you can follow our how-to series of photos on wheel lacing) may be able to benefit by replacing the stock wheel, using longer spokes and a rim with the spoke holes drilled at a greater angle. The vast majority of production motorcycles, regardless of whether they are intended for street use, road racing or off-road racing, have their wheels laced with the spokes in a pattern where each spoke crosses one, two or three others. This is fine for road use.

The giant drum brakes used on some road racers also affect their spoke pattern in that they reduce the space between the hub (brake drum) and the rim so that there just isn't room for the spoke to lie at much of an angle. A road racing machine will often have only a "cross one" or "cross two" spoke lacing pattern. Because of their lighter weight and power, the smaller machines don't require more than 36 spokes, but there is a financial savings involved over fitting 40 spokes—four spokes-per-wheel on a run of 10,000 lightweights saves 80,000 spokes.

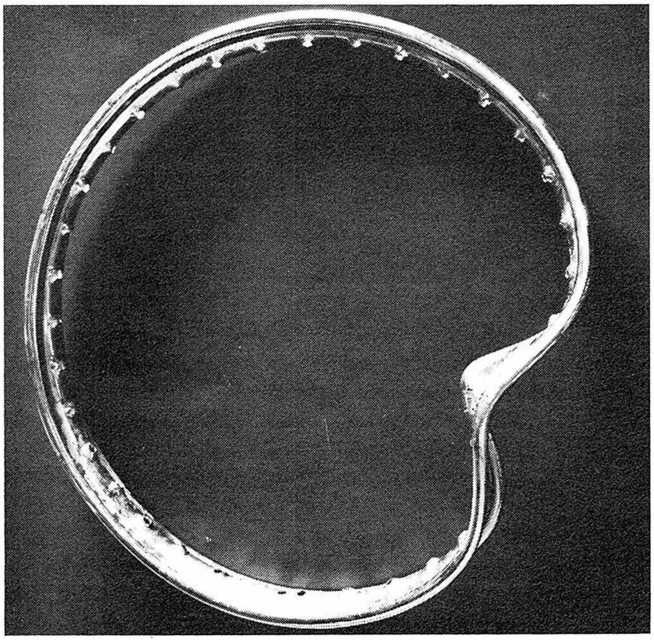
Wire wheel spokes are available in a variety of diameters and materials as well as lengths. The spoke itself may be either the common nickel-plated steel or stainless steel. The majority of the wheel-lacing experts claim that the strength characteristics of each type are practically equal but

WHEELS

that the stainless version is superior in resisting corrosion. If you race your machine, you should avoid a chrome-plated spoke; the chrome plating process leaves the surface of the spoke brittle (an engineer would call the effect "hydrogen embrittlement") and the spoke may break easier than one that has the factory-stock nickel-plating. Most wheels are laced with spokes having a diameter about equal to steel-wire gauge of 8 to 12. If you are relacing a wheel for use in off-road racing, you'd do well to consider a larger diameter No. 6, No. 8 or No. 10 gauge spoke, particularly for the rear wheel. A road racing machine's wheels are best laced with a smaller No. 10 or No. 12 gauge spoke that will provide as much of its own shock-absorbing capacity as possible.

The long, thin nuts that screw onto the rim end of the spoke are called nipples. You have a choice of nickel-plated steel, stainless steel, chrome-plated brass or aluminum nipples if you're willing to search among the wheel parts suppliers. Most Japanese machines are equipped with brass-spoke nipples but the wheel rebuilding experts prefer nickel-plated steel nipples. Aluminum nipples will save a few precious ounces of weight for the serious road racer. You should always buy matched sets of spokes and nipples to be sure that the threads are precisely the same. Spoke and nipple sets run between 35 cents and 42 cents apiece, depending on the material. A plated steel nipple usually sells for 12 cents and an aluminum nipple for 14 cents.

It's obvious enough that the wheel diameter must match the tire's inside diameter (i.e. a 21-inch wheel needs a 21-inch tire). What's not so plain is that the width of the wheel's rim must also be matched to the tire's width (called the "cross section" of the tire) which is ultimately determined by clearance within a given motorcycle chassis. The drawing illustrates just where the width of a wheel's rim is measured. Notice that the dimension you want is definitely *not* the overall width of the rim, but the width of the area that keeps the tire's inside edge (called the tire "bead") on the rim. The tire and wheel manufacturers have adopted an International stand-



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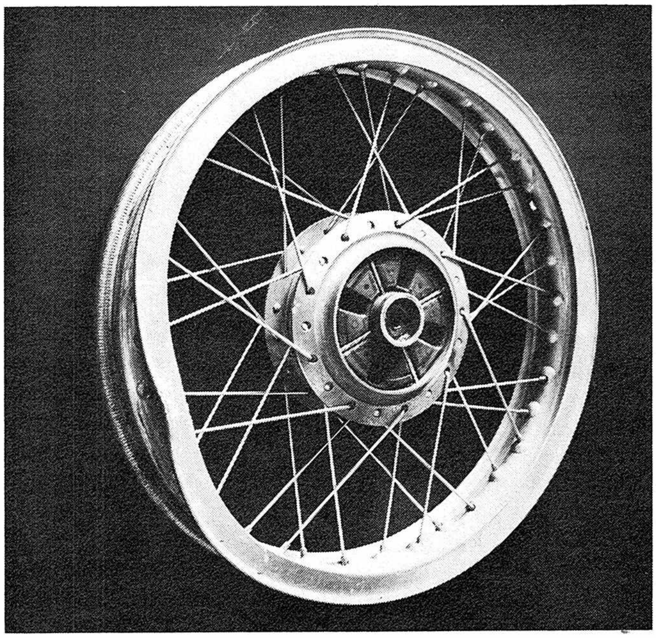

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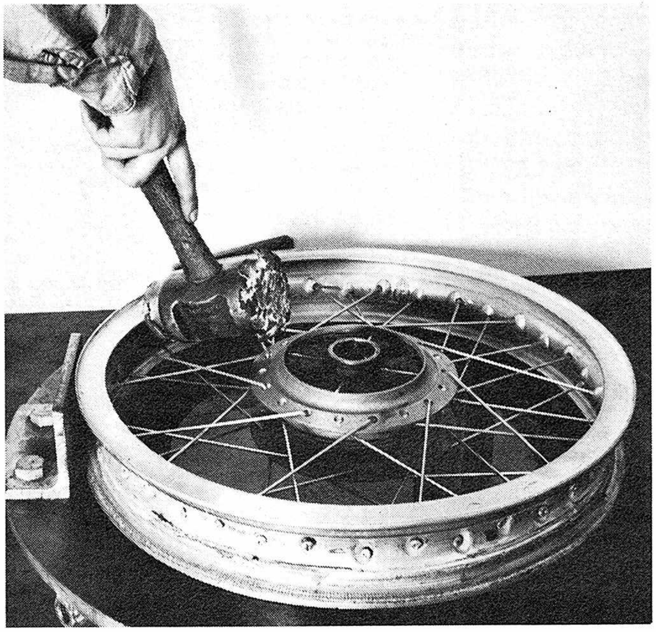

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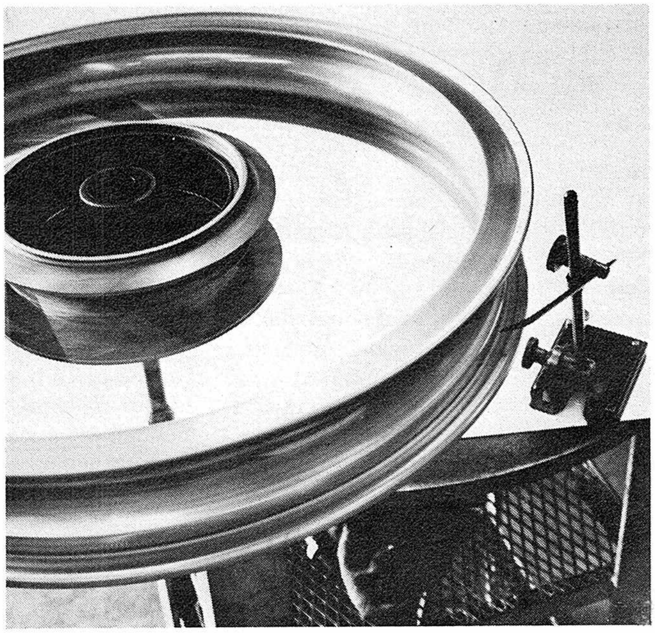

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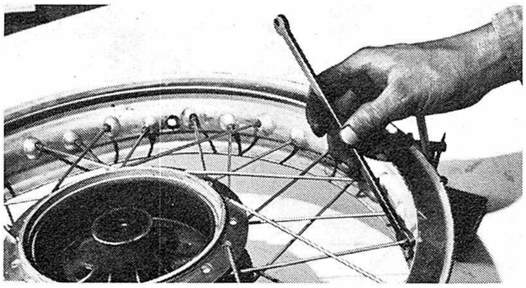
ard set of markings for motorcycle rim widths that have next to nothing to do with their actual dimensions. The following chart will give you the rim-width marking that is usually stamped on the rim, the actual rim width, and the range of tire widths that a particular rim will accommodate:

Rim No.	Actual Rim Width	Maximum Tire Cross Section
WM-0	2 inches	2.25 to 2.50
WM-1	2¼ inches	2.50 to 3.00
WM-2	2½ inches	3.25 to 3.50
WM-3	3 inches	3.50 to 4.00
WM-3.5	3½ inches	5.00 to 6.00
WM-4.00	4 inches	5.00 to 6.00

The tires made by all of the manufacturers are engineered to take their designed shape only when they are mounted on the correct rim width. If you're mounting much wider tires on your machine, you'd best consider replacing the rim as well if you expect to gain the full advantage of the increased tire width.

Combined wheel and tire diameter, and cross-section, although usually ideal for a given machine under normal circumstances, occasionally involves a compromise that may not be necessary for a personalized application. The off-road boys experiment all over the place, playing with different tire diameters and widths. Generally, however, they come back to the same conclusion of the original cross-country racers, the early American pioneers, who found that the larger diameter wheels of their covered wagons put down a longer footprint which bridged the innumerable chuck holes which plagued their path. Larger diameter tires don't fall into nearly as many holes or ruts that tend to swallow a smaller hoop and deviate its course.

The fat vs. thin front tire controversy still rages. There is no cut and dried answer, for much has to do with riding style, engine power, weight of machine and type of terrain. The faster rider, capable of lofting the front wheel upon command, is less conscious of the weakness of a tall, thin front wheel and tire for he is able to lift it over the hard stuff and is more appreciative of its generally better cornering ability on fire roads. And theoretically, having less unsprung weight, the lighter front wheel and tire should prove more responsive to road irregularities. Also, in mud, the thinner tire is less apt to load up and jam. But try and tell that to the handler of a big desert sled, who wants that extra cushion of a fat 4.00 sausage to iron out his straight-ahead charge over the tulies The 4.00 is also easier for the



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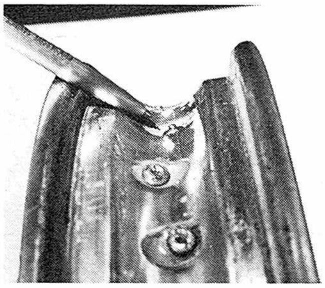

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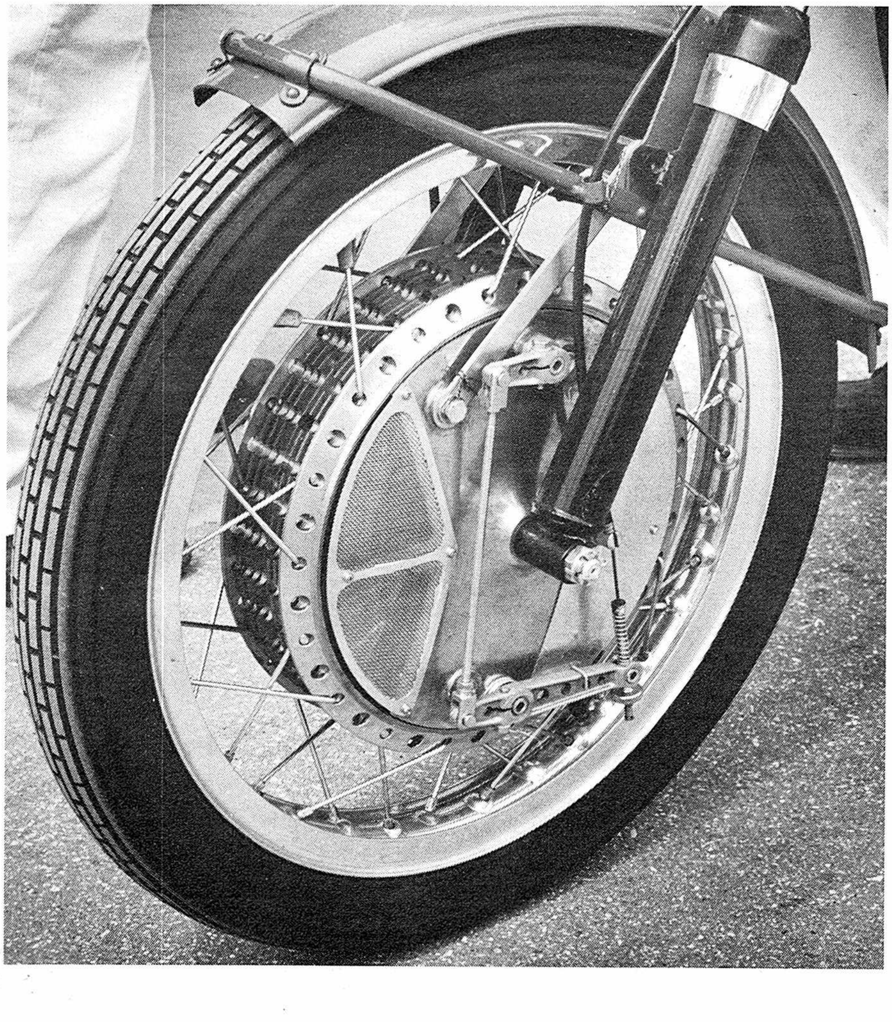


7

1. Horrors. This is one of the worst rim disasters we've seen. Poor devil hit a curb at an angle at high speed and experienced one of the most incredible endos in history. The rim, of course, cannot be repaired.

2. This rim can be repaired and anybody thinking of competing in the rough had better know how because even super-strong alloy hoops bend regularly in the rocks and stumps.

3. Set the rim against a backstop for the hammer's blows. Now bang away with heavy fiber-inserted hammer or a soft lead or brass mallet.

4. Set up a pointer just a fraction from the rim flange after fitting wheel on its axle or same size bolt and secure in a vise. Make sure the wheel spins freely. Dial indicator vice or the like holds a pointer nicely. Spinning the wheel as shown will bump the pointer at the point of runout or out-of-roundness.

5. Buchanan's spoke wrench or small Crescent will fit spoke nipples best. Spokes on the 'high' side of runout are tightened no more than one full turn each time. Usually spokes opposite the wobble must be loosened the same amount. Equal tension on all spokes is the goal. When all the spokes have the same ring when tapped with a wrench, the job is right.

6. The last step is to grind or file the spoke ends flush to prevent tube damage. After they're flush with the nipple head you might cover the center 'U' groove with silver duct or masking tape. Keeps moisture out.

7. Large diameter four-shoe racing hub limits space for sharp angling of spokes. Small space between hub and rim means only a 'cross 1' pattern is possible with 36-spoke wheel. Great strength of the hub and alloy rim give the wheel sufficient rigidity for road racing. Spokes are tightened, wheel trued after each race.

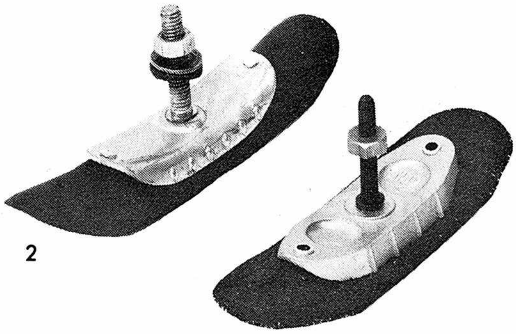
beginner, at least, to steer in deep, rutted sand, having less tendency to "hunt" than the 3.00. The trick with the 3.00 in soft stuff is to ride light on the bars, letting it seek its way (within limits), for it will usually go fairly straight if the operator doesn't try to man-handle it under such circumstances (depending, too, upon the speed involved). Of course, engine displacement enters into the picture. Some of the 200cc-and-under machines are short on power to overcome the fat hides, in which case the tire must be proportionate to chassis weight and engine displacement.

Surprisingly, the different wheel diameters are nearly offset by the larger tire widths so that both a 3.00 x 21 wheel and tire and a 4.00 x 18 wheel and tire have about the same overall diameter. Those first three numbers of any tire's size refer to its width and height as seen in a cutaway drawing; this is why the tire folk call those numbers the tire's "cross-section." The cross-section height of most tires is roughly equal to their width so that a 4.00 x 18 tire, for example, is about four inches wide and the inflated cross section is about four inches high. You can determine, then, the approximate diameter of a tire by adding twice its cross section dimension (there's a tire cross section at both the top and the bottom of the rim, remember) to its rim diameter. That 4.00 x 18 tire will add up as 4 plus 4 plus 18 inches for a total of 26 inches overall inflated diameter. A 3.00 x 21 tire would measure about 27 inches in diameter (3 plus 3 plus 21 inches). You can see, then, the two apparently different tire sizes have overall diameters that are close enough to one another to keep the machine level and evenly balanced for off-road racing.

Motorcycle rims are also available in a choice of materials including chrome-plated steel, painted high-tensile steel and aluminum at prices ranging between $18.00 and $30.00. All but the really high-performance street or cafe racers and ready-to-race moto-cross production machines are supplied from the factory with plated steel rims. For anything but serious racing (or frequent play racing) stock rims are fine as long as their width and diameter are suitable for the tires you want to use. The lighter weight high-tensile steel or aluminum rims will save some weight and offer more strength than the stock rims. The BSA factory-prepared moto-cross machines that competed in the 1970 Trans-AMA professional series and in the European Championship Moto-cross races were fitted with Dunlop's painted high-tensile steel rims. These rims are nearly as light as aluminum (and far stronger) but they are expensive and, as of now, not available from any American importer.

You do, however, have a choice of

1



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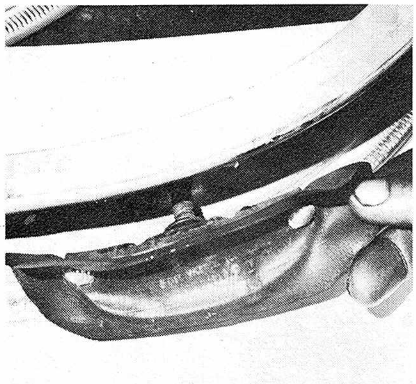

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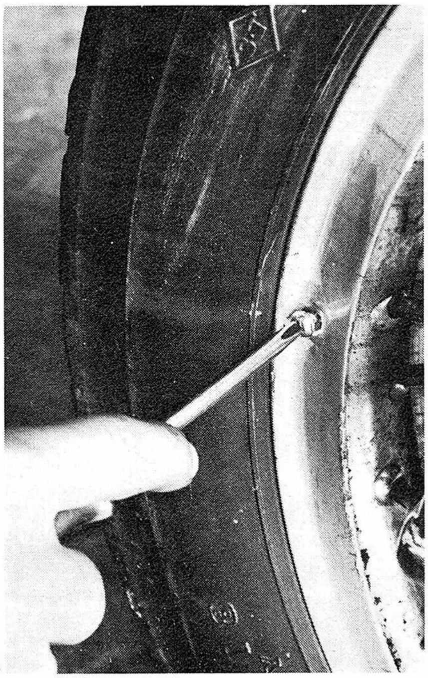

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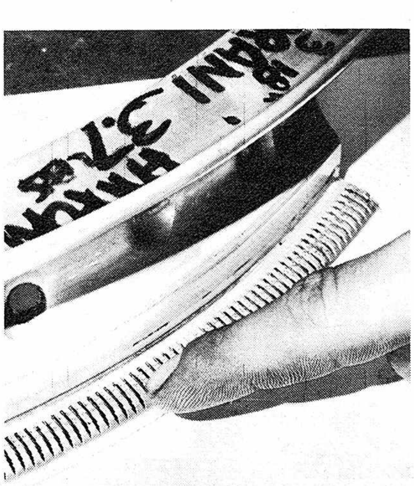

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1. Just the right combination of braking, acceleration and sharp shock (note bent rim at 2 o'clock) tore this hub apart. This failure can be arrested with 'cross 4' pattern that makes opposing spoke pairs pull at a tangent to the hub's circumference and at each other. This failure was caused by a combination of wrong spoke pattern and a weak hub.

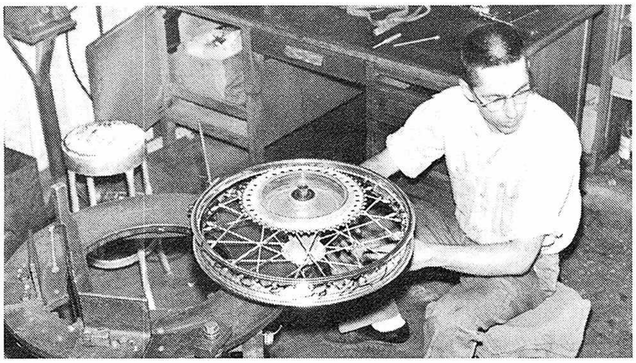
2. For dirt riding there's no replacement for tire locks (security bolts, rim clamps, etc.). These beauties fit under the inner tube and when tightened pinch the tire bead against the rim. This then permits the air pressure to be very low (or even flat) without the tire spinning on the rim, tearing the valve stem.

3. Rubber cover on the back side of the tire lock protects the tube from damage or corrosion of the metal frame. Locks are sized to rim width.

4. Street riders, drag and road racers often use sheet metal screws in rim and tire bead to eliminate slippage without throwing wheel out of balance from heavy locks. Riding on a flat for long will tear tire bead.

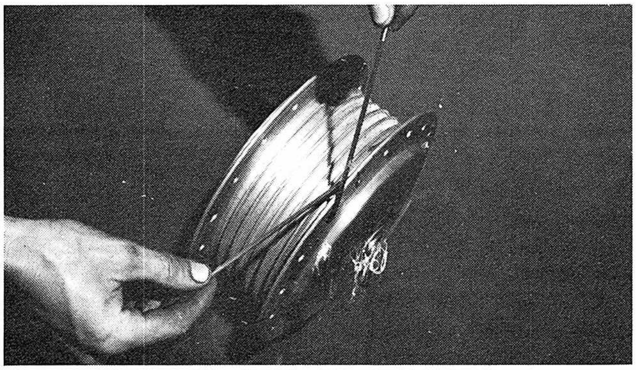
5. Some rims come with serrations to arrest tire slippage. Serrations are most effective at tire lock or screw location. If rim is smooth a sharp chisel will make nice serrations.

HOW TO: Lace Your Wheels

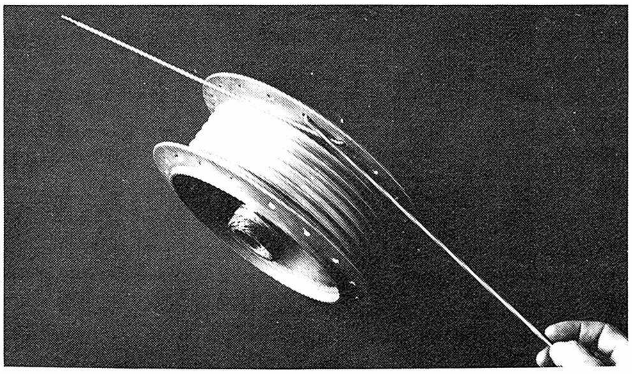


1. Your garage may not have all the jigs and special tools of our instructor, wheel and frame specialist Jim Buchanan, but you won't need them if you go step-by-step. Keep all of the spokes and nipples from your old wheel.

2. Complete relacing is required whenever you change either hub or rim. Here we'll lace up a 21-inch Akront to a Maico front hub. If you are not positive about spoke length ask an expert to compute what you'll need.



3. Most standard motorcycle wheels are laced in a cross 2 pattern, wherein each spoke crosses two others between the hub and rim. Factory lacing of the Maico hub would angle the spokes like this, not ideal for maximum strength.



4. 'Cross 3' or 'cross 4' (as shown) gives maximum strength for racing, particularly off road. Here the spokes angle closer to the hub, and in total their stress is more inward. This holds hub together, doesn't pull out.

two different brands of aluminum rims: Borrani or Akront. Aluminum rims are lighter than steel because the material itself is lighter; but they're also a bit weaker if both are made to the exact configuration. Both brands of aluminum rims have an I-beam shape beneath both tire beads to give them even more strength than a steel rim. A typical WM3-18 steel rim weighs 6.1 pounds, the Akront-brand 4.4 pounds; all without any spokes, hub or tire. The experts at the wheel shops we visited claim that they see more bent Borrani rims than Akronts. The weight savings between these two may be the result of a bit less material in the Borrani, but it may be worth it to a road racer.

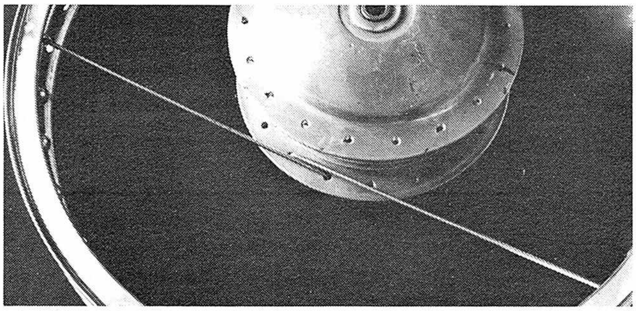
If you're in the habit of running your machine at racing speed, give some thought to keeping the tires from spinning on their rims. The tried-and-true method is a device aptly dubbed security lug or security bolt. The lug is a piece of rubber-lined steel, about four-inches long, shaped like a tiny trough with a bolt protruding out the center of the backside of the trough. The amount of rubber varies with the brand of lug but it is always shaped to match the dropped center area of the rim, extending up to catch a good ¼-inch of the inside edges of the beads of the tire. The lug literally clamps the beads of the tire between the sides of the trough and the edges of the rim. The sides of the trough are tapered a bit so that when the bolt (that protrudes through the rim like a valve stem) has its lock nut tightened, the security lug grips the inside edges of the tire's beads between it and the rim. Only one security lug is required for each wheel. The device works just fine if you can master the trick of mounting the tire and tube on the rim without pinching or tearing the tube. The experienced competitors in the International Six Days Trial can do it in around four minutes.

Road racers and drag competitors are borrowing a trick from the automobile racers and drilling a half-dozen or so equally-spaced small holes into each side of the rim. Self-tapping sheet metal screws are then screwed through the rim and into the bead area of the tire to secure the tire and prevent slipping. The screws must be short enough to stay within the bead area of the tire, with no chance of ripping into the tube.

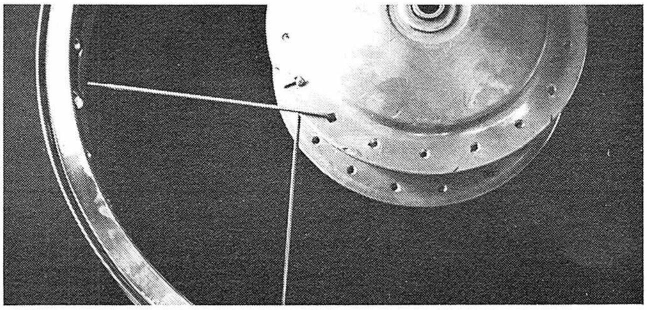
If you're using alloy rims on a road-touring or road-racing machine, the serrations that are rolled into the inside bead area of these rims will often be enough to discourage the tire from twisting around the rim diameter under hard acceleration or braking. The tire company's recommended inflation pressure is enough to keep the beads in touch with these serrations—but the only way to be sure that your tire won't slip on the rim and rip off the valve stem is to use one of these tire-clamping systems.

There is seldom any reason to replace the hub of your wire wheel with anything other than the stock item. If you are constantly breaking hubs, the wheel can be replaced with longer spokes in a pattern with the spokes

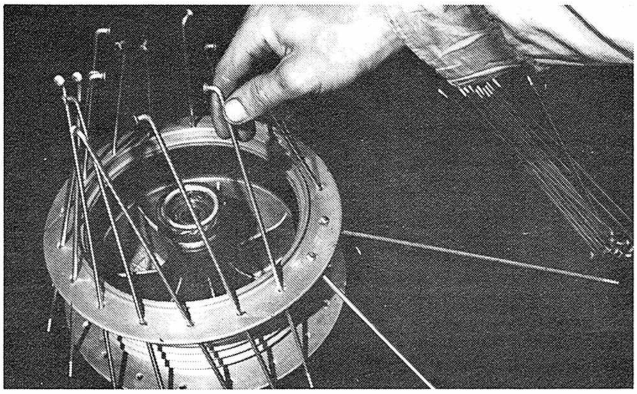
HOW TO: Lace Your Wheels



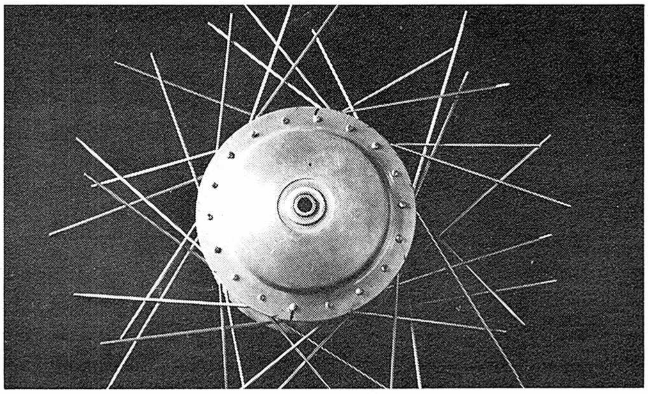
5. *Each opposing pair of spokes in the 'cross 4' pattern will cross as shown. Longer spokes are required for stock lacing and the task is more demanding. This pattern obviously acquires maximum hub life for racing.*



6. *Standard 'cross 2' lacing begins like this. On Maico and some others, one spoke exits from the outside and the other from the inside of the hub flange unlike the 'cross 4' pattern. To copy standard lacing, use same rim.*



7. *In the 'cross 4' pattern our demonstration starts like this. Thread the spokes into both hub flanges, all exiting from the inside. If the spokes are larger diameter than stock. drill out the holes, don't force them through.*



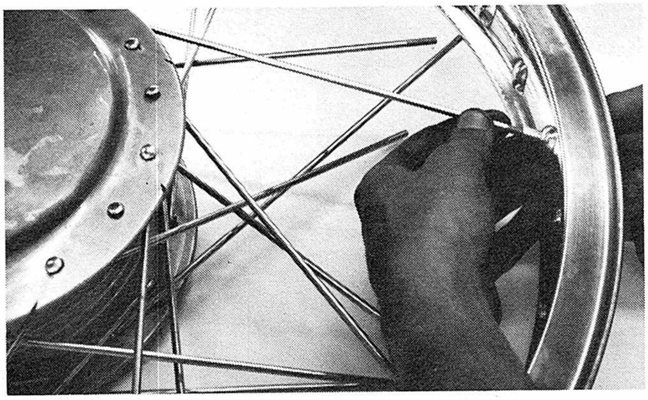
8. *Arrange the spokes in the exact pattern that they will lace by using the rim as a guide. Spokes on the same side of the hub that pull in the same direction, should enter every fourth rim hole. Keep work area clean.*

WHEELS

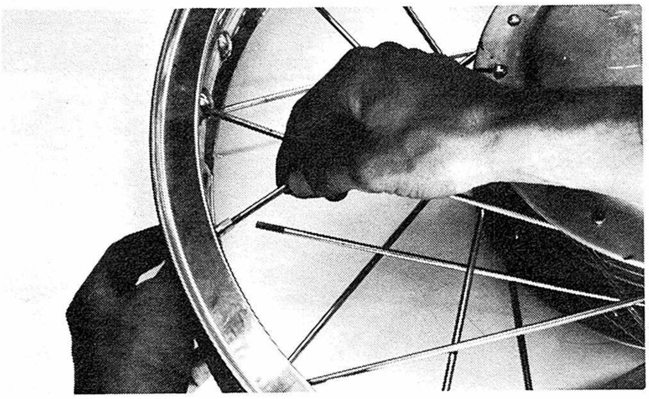
lying closer to the hub so they angle farther from vertical between the rim and hub. The spokes will then cross over more of their mates than stock so that if, for example, the stock lacing pattern was what we've described as a "cross two," you can relace the wheel in a "cross three" or "cross four" pattern. With the spokes pulling at a greater angle they actually tend to help hold the hub together rather than pulling it apart under load strains.

Many of the newer factory production moto-cross racers, and some street machines, are fitted with what are called "conical" hubs. These hubs have a brake on one side with the spokes laced into the edge of the brake drum. The side of the hub opposite the brake is as small as it can be and still leave room for the bearings and spoke holes. The hub is shaped like a cone to reach from the small flange diameter to the larger diameter of the brake drum and that's where it gets its name. There is less material in most of these hubs than in those that have a nearly constant diameter all the way from one spoke-attaching flange to the other. Some of them are even fabricated from welded sheet steel rather than being cast aluminum. If you're considering relacing your wheel, for whatever reason, you might consider the weight-saving advantages and possible greater strength of the conical hubs. You may save a pound or two on each wheel, but the only way to tell is to contact one of the suppliers of these hubs to find out if they have a hub to fit your machine and what it weighs; then you'll have to disassemble your wheel to weigh your stock hub. You can, of course, save even more weight by eliminating the brake system entirely for drag racing or (if you insist—we won't recommend it, ever) for a street chopper. In both cases, though, you'd better check with the "law." Most of the drag race sanctioning groups now require brakes on both front and rear wheels and many states have laws pending that will require the same (or a proven stopping capability) of all street-legal machines. Since the vast majority of braking efficiency is achieved with the front brake, due to forward weight transfer upon deceleration, removal of the front brake is not only ill-advised, it is downright lethal.

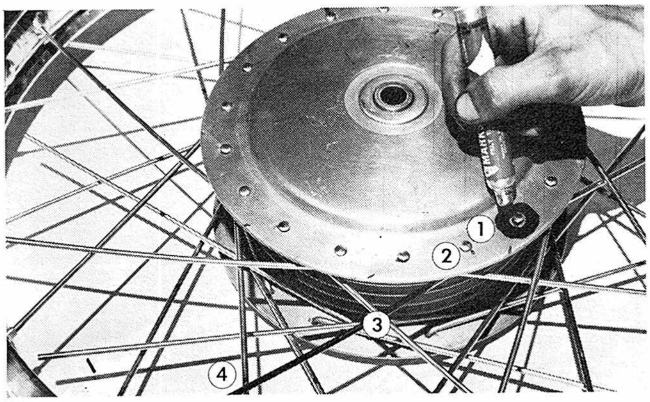
A complete wire wheel relacing job is the perfect example of the classical Chinese puzzle; the parts look like they'd just about fall into place—they don't. We can't tell you how to completely relace a wire wheel without resorting to hand signals, so we did just that; check the sequence of photos and captions for the proper procedure. Here are the steps that experienced wheel repairmen (in this case, the men at Buchanan's Frame Shop in Monterey Park, Calif.) follow; we hope you can do as well. Don't try it at 3 a.m. in the morning before a race. Give yourself at least a few nights to get the hang of what goes where. The best tip we can give is to suggest that you have a duplicate, assembled, sample of the exact wheel you're trying to relace to use as a reference point. For further reference



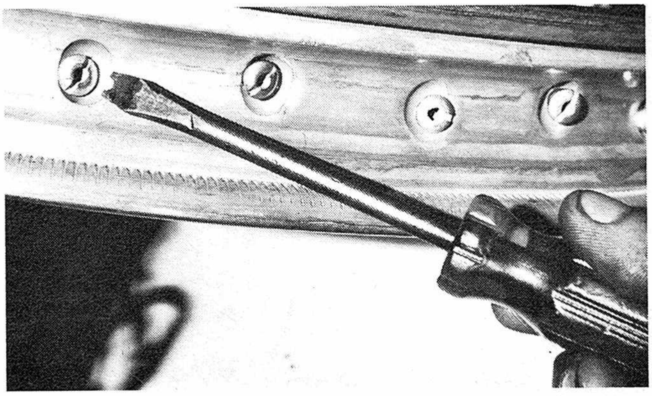
9. *Place the rim over the spoke layout carefully and connect each group angling in the same direction first by threading the nipples finger tight. Rim holes are drilled to the angle of the spoke pattern upon order.*



10. *Next lace the spokes that cross in the other direction by threading on nipples. Attach all the spokes on one side of the hub, then lace the other. Don't try spinning the wheel. Move your body around, not the wheel.*



11. *To clarify the 'cross 4' pattern we have inserted a black spoke. The black circle is painted spoke and the four numbers show the crossing sequence. Thread the nipples only a few turns on the spokes for adjustment.*



12. *Modifying a screwdriver as shown for nipple tightening gives clearance for spoke. Start by tightening until 1/32-inch of thread comes through top of nipple. A dab or kerosine or solvent on rim hole reduces friction.*

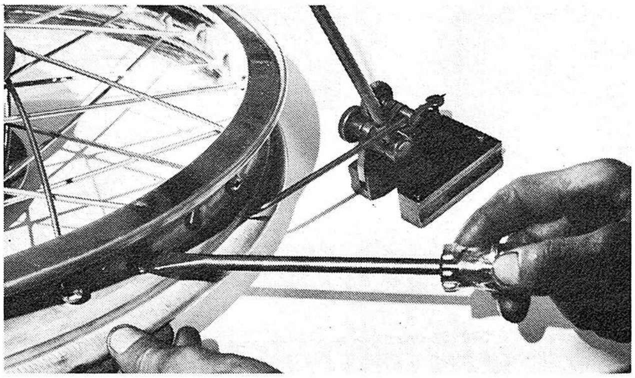
you might check with the shops listed in your local telephone book's yellow pages under "Wheel Alignment, Frame & Axle Servicing—Automotive" or with your local motorcycle dealers to find a nearby "expert."

You will find it far easier to "tune" and adjust your wire wheels than to completely relace them. The various spoke's nipples around the rim can be loosened or tightened to adjust the rim so that it is pulled into concentricity with the axle. If one or both of your wheels wobbles, with no noticeable dent in the rim, you can safely assume that some of the spokes are too loose or that some ham-fisted tuner has over-tightened some of the nipples. Wire wheel truing is almost an art. Each of the spokes should be just as tight as the next; giving off a crisp ringing sound (assuming there is no glob of oil on any of them to dampen the sound) when tapped lightly with a wrench. To check a wheel for wobble, prop the offending end of the machine up off the floor so you can spin the wheel—the bearings and brake must be adjusted properly so the wheel will spin for a minute or so before coasting to a stop.

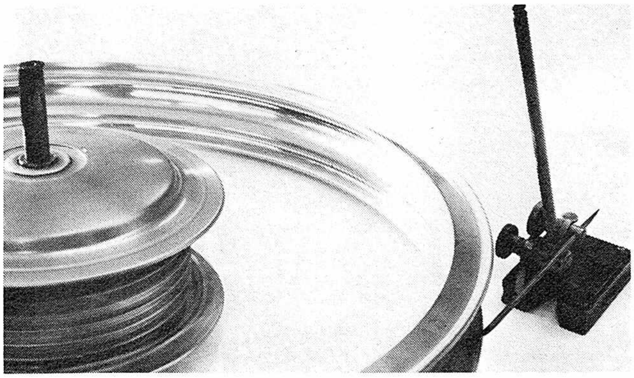
Block up some type of metal pointer to act as an indicator so that it is just a fraction of an inch away from the inside edge of the rim. If the wheel is running absolutely true, the distance between the indicator's point and the rim will remain constant through an entire rim rotation. If the rim wobbles, the pointer will help you to spot just where the wobble is and whether the wobble runs out toward or away from the pointer. Remember, wheel wobble can result from both lateral (side-to-side) and radial out-of-roundness. Again, the pointer will let you isolate which (it could be both) type of wobble is present. If the wheel has a lateral wobble, it can be corrected by loosening the spokes on the wobble area that are on the bulging side and tightening those that lead to the opposite side of the hub. During adjustment, listen for the ever-constant "ping" when they're tapped with the wrench—after a little practice you can tell from the feel through the wrench handle how loose or tight the spokes are.

Always apply a drop of thread lubricant to each of the nipples a few hours before you adjust any spoke. The lubricant will loosen most seized threads and it will help to give a constant feel to each of the spoke nipples as you are adjusting them. An automotive ignition wrench set will usually include one open-end wrench that'll fit those nipples, or you can buy a special wire wheel-adjusting wrench (to fit a sample of one of your nipples) for $8.00 from Buchanan's. If you have determined that your wheel has a radial out-of-roundness, the spokes on the high side will have to be loosened and those on the diametrically opposite low side tightened to true the wheel. When working out a wheel wobble through spoke adjustment, loosen two or three of the spokes in the offending area about one turn each. The half-dozen spokes on either side of the wobble area should be loosened progressively less than that full turn to spread the adjustment evenly. Take your time, working a

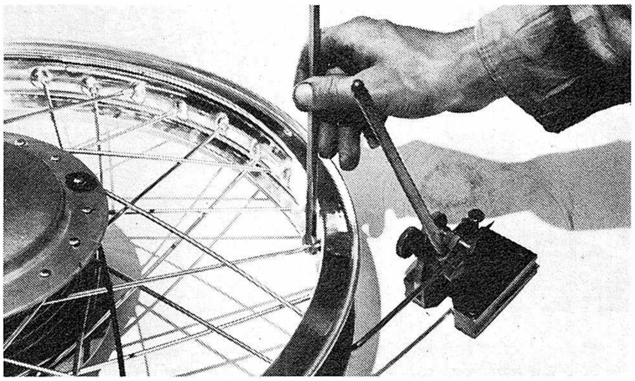
HOW TO: Lace Your Wheels



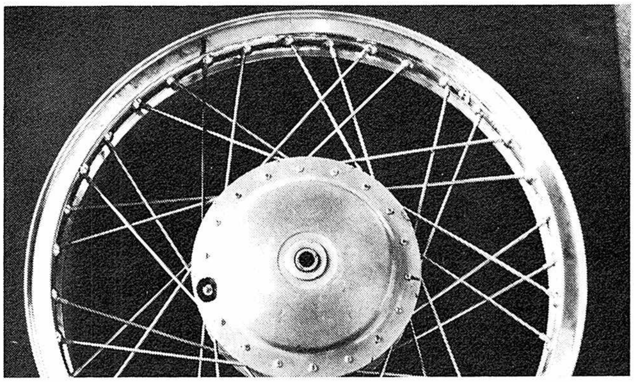
13. Place the wheel in its axle or a same size bolt and spin with a pointer (a coat hanger wire will do) 1/32 inch from the inner corner of the rim flange. Tighten the nipples with the special screwdriver.



14. Spinning the wheel enables quick isolation of runout and subsequent tightening or loosening of spokes. This is the same process used to true a new or used wheel. Spinning and tightening is done until wheel is perfect.



15. Final tightening should be done with spoke or wide small crescent wrench. Some spokes may have to be loosened a bit to allow tightening of others for the final pinpoint trueing. Result should be as good as factory.



16. When completed each spoke should have the same solid ring when tapped with wrench. Note how the hub now hangs from the black spoke and opposite one at 3 o'clock (90° to the right). Geometric shape and design insures strength.

WHEELS

maximum of a single turn of the spoke's nipples at a time. If you make a mistake in loosening or tightening the wrong spokes, they can then be quickly readjusted to their original setting. All of the work can be done with the wheel on the motorcycle just as long as you don't have to tighten one or more of the nipples any more than two full turns. If you have to tighten a nipple that much to adjust out the wobble, you may just move the threaded end of the spoke enough to rip through the rim band and into the tube. If you have adjusted any spoke nipple that much, you should remove the wheel and dismount the tire to check to see if there is a need to grind off any now-protruding spoke ends so they're once again flush with the tire-side ends of the nipples.

Don't necessarily expect the rim to be centered over the hub (as viewed from the head-on front or rear of the motorcycle). The rim on some machines is offset to clear either the brake or the chain—if in doubt the only way to be sure is to check another machine just like yours to see where the rim is positioned.

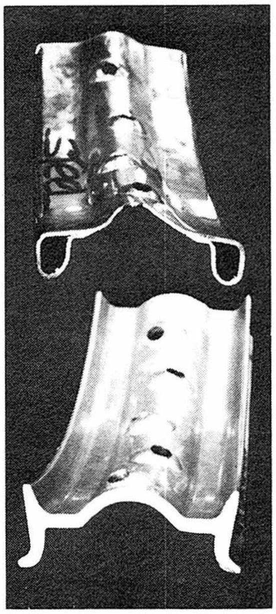
If you're one of those riders who is extremely conscious of saving weight on your machine, you may have already mentally computed that you can save as much as four or five pounds per wheel by replacing the steel rim with one of aluminum, and by replacing your full-width hub with a conical hub. It sounds like a ridiculously small amount; you could save that much by going on a weekend crash diet to save rider weight. The weight we are talking about, however, is unsprung weight and that makes it rather special. The front forks and rear shock absorbers and their springs are there to control wheel movement in an effort to keep the wheels and their tires in contact with the ground as much as possible. You cannot do much steering, stopping or accelerating if the tires are up in the air. The heavier the tire and wheel (and, of course, the brake, axle, bearings and lower half of the fork and shocks), the higher they'll bounce after each bump and the harder it is for the forks and rear shock absorbers to control them and keep them on the ground. Every bit of weight below the front and rear springs is part of the unsprung weight which the forks and shock absorbers must control. Since a typical front tire and wheel assembly complete with brake (a Kawasaki Mach III) is about 43 pounds, a savings of four pounds is nearly 10 percent—it's beneficial effect on the machine's handling can be nearly as great as trimming 10 percent off the total weight of the bike and that would have to be nearly forty pounds! This is the reason, other than potentially greater strength, why so many road racers and moto-crossers have aluminum rims and/or lightweight hubs. Cast alloy wheel assemblies can save even more unsprung weight for the road racer or street rider.

Road racing automobiles abandoned the wire wheel years ago because of the tremendous side-loads imposed by the car when subjected to G-forces in a turn. But motorcycles fortunately do not inherit this handicap, so have been slow in taking up with the popular cast wheel or "mag," as it is known. Now, however, there is the persistent effort to introduce the mag to motorcycledom, with several firms offering this novel cast wheel in a variety of configurations. Although they have yet to prove themselves in all forms of motorcycle sport, they do provide meat for interesting speculation, and possibly the solution to some of our problems (minor though they have been on the whole). The spoke has been mighty good to us and could yet prove to be the ultimate answer.

There's little chance that the off-road racers will want to use cast alloy wheels. The flexing of the spokes, as the machine's weight hangs off of them, serves as a much-needed spring for the off-road racer that helps to keep the wheel from destroying itself and the rest of the machine as well.

There are two major brands of alloy motorcycle wheels currently available in this country. Both brands, Tabloc and Monotrack, require that you replace the brake as well (unless you're replacing the front wheel on a disc brake-equipped machine). It is, apparently, not possible for the alloy wheel makers to produce all of the different wheels it would require to retain the stock drum-type brakes.

Both brands offer potential advantage over the wire wheel, that of controlled trueness. Alloy wheel castings can be machined to a lateral and radial runout tolerance of .001-inch—a good wire wheel-truing man can hold to about .003-inch, sometimes less, so it is close. Tabloc offers two sizes of wheels, a WM3x18 and a WM3x19. Monotrack can supply 16, 18, 19, 21, 22 or 23-inch diameter wheels in any width the customer specifies from a measured 1.75 inches to 6.10 inches. In any event, you'll have to agree they contribute to the world of wheels.



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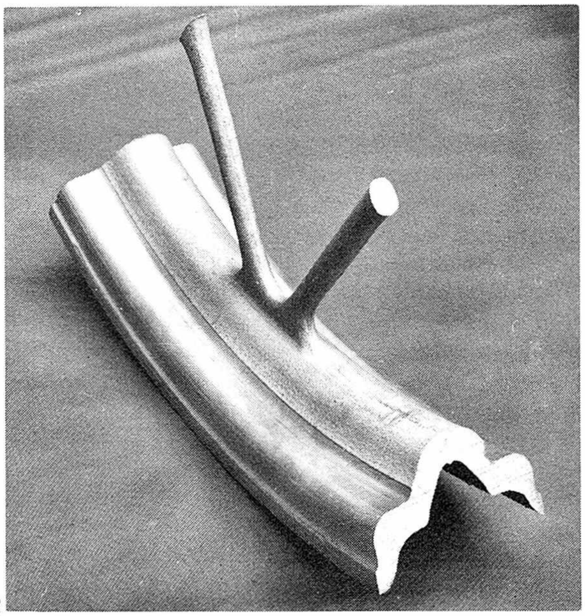

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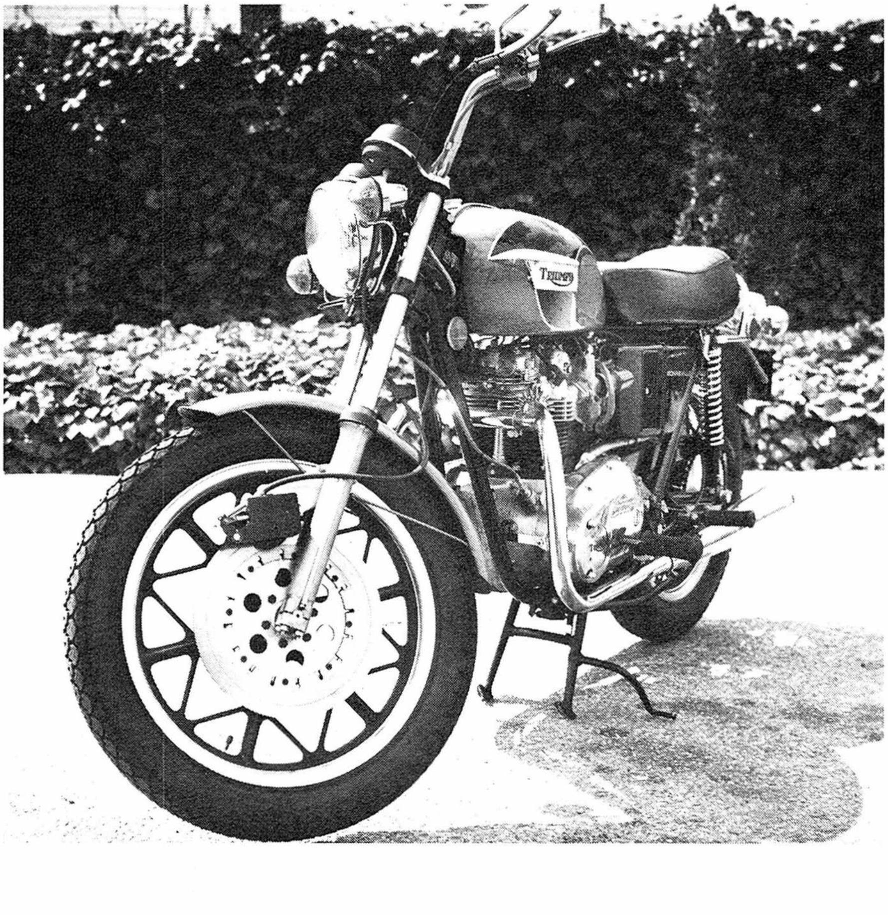

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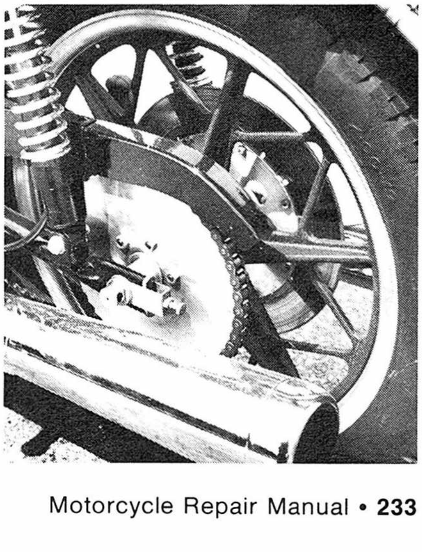

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1. Cross sections of Akront aluminum (top) and typical WM-3 steel rim show additional strength gained by 'I' beam design feature of alloy hoop. Alloy rim is 30% lighter also.

2. Tabloc magnesium rim has thick, well radiised sections. Rim is centrifugally cast then machined to .001 inch tolerance. This 'rim of the future' is also Zyglo tested. Large 'X' sections of spokes do major load support, yet are light.

3. Tabloc Snowflake mags are natural to give that custom/sporting look to the Triumph Bonneville. Disc brake can also be supplied by Tabloc, although Honda and other Japanese discs will fit the wheels.

4. Rear end of Triumph takes on all new look with mag wheel, sold sprocket and disc brake. It may not be in the too distant future that motorcycles will have tubeless tires.

CHASSIS DESIGN AND CONSTRUCTION

A maze of triangles, welding and steel tubing, but understanding frame design will expedite modification or rarely-needed maintenance

BY DAVE HOLEMAN

Motorcycles, all types, are comprised of a series of components that when all put together provide the power to go and stop and turn corners and absorb bumps. Sounds simple enought, but a new motorcyclist is not a motorcyclist very long before he realizes that some machines do all of these things better than others. And this in spite of the fact that the various components appear identical in function if not in design. Why?

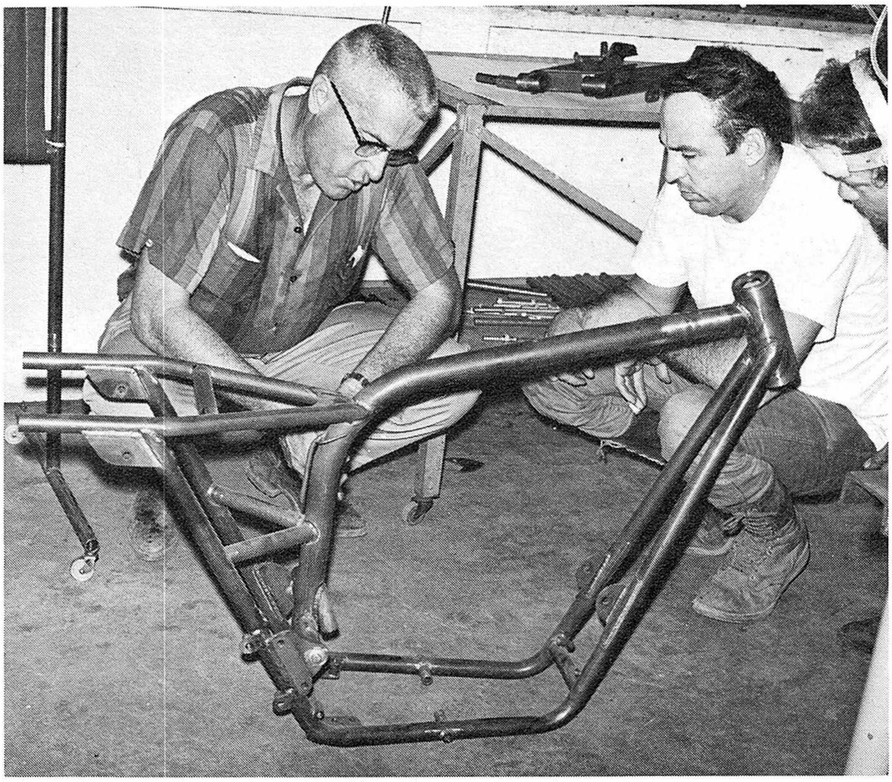
If you are a genuine motorcycle enthusiast who enjoys knowing all there is to know about motorcycles, you have doubtless read many books and magazines covering the subject. Engine theory is popular, and many of the theories are proven by representative examples from the world's manufacturers. Theory tells us that the route to high horsepower is many cylinders. The three, four and six-cylinder engines used in the most successful road racing machines bear this out. Theory tells us that lots of brake lining area is the best way to get a vehicle stopped. The monstrous brakes on those same road racers would seem to indicate that this theory, too, is correct. But what about the chassis? Where do you find the textbook that lays all there is to know before you? If you find one, send a copy.

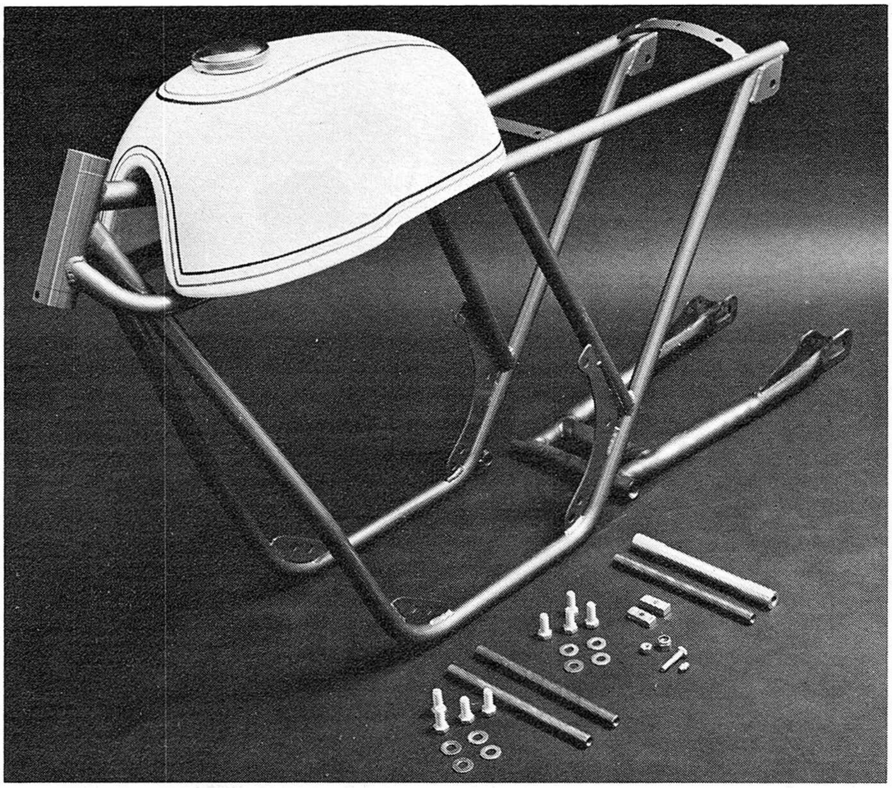
Because of the fact that a motorcycle chassis, frame and swing arm, has only a few moving parts it should never wear out, require overhauling or rebuilding. The only places where there is any frictional movement is at the swing arm pivot, fork crown bearing surface and rear shock absorber bolt mounts. Here, all that is needed might be a rare replacement of the swing arm bushings should they wear enough to permit the rear fork to move side to side. The fork crown bearing surface is most always a set of races that are pressed into the frame head stock. Again a rare occurance is replacing these races with new ones should the fork assembly loose in the head stock and adjustment won't take up the slack. That's about it for any moving parts that might wear out.

There are no moving parts in chassis, but the frame of a motorcycle does work. Particularly with tubular frames and swing arms the chassis must flex just enough so as not to give or break. Too rigid a frame will react like it is too brittle and break or crack at its weakest points. Too flexable a chassis will give and bend to the point of collapsing and breaking. In the middle are hairline cracks and fractures that come from borderline design or marginal materials. Naturally these small hairline cracks can lead to disasterous breaks. The most common victims are off road machines and large, high horsepower superbikes. And if you might think frame failure isn't a common problem with the new superbikes a candid visit to the warranty departments of any of the manufacturers would open your eyes to a prevalent problem.

The problems that do occur with motorcycle chassis are directly related to the work load put on it. Our resident engineer Bill Ocheltree, put the engineering aspects of chassis design into a few well chosen sentences as follows.

"The speed at which a force is applied to a material will cause it to show different strength characteristics. A very rapidly applied shock load in excess of the ultimate strength may not cause failure under certain ideal conditions, whereas a shock amounting to a small fraction of the maximum load will cause failure under more adverse conditions. The actual conditions under which impact failure occurs are so varied that it is difficult to place specific values on the impact resist-





1. Production frames are generally a replica of specialty chassis designed to perform perfectly in competition. Large tubular backbone enhances strength while keeping weight minimal.

2. Specialty chassis kits have become quite popular for many of the Japanese small-bore bikes. If properly designed and engineered, small lightweight tubing will withstand great work loads. Long swing arm has cross brace for lateral rigidity.

ance of various materials. Therefore, attempts are made to avoid or minimize shock loading by absorbing the loads over as long a time period as possible.

Virtually no loads imposed on a moving vehicle can be considered static. The basic loads from which design calculations are made, to determine the strength required are always expressed in dynamic terms. External forces are generally based on acceleration rates in various directions and are expressed in relation to the weight involved in "g"s. One "g" is an acceleration rate of 32.2 feet per second per second or the acceleration produced by the earth's gravity on a free falling object. The weight of an object is the force it exerts against a scale due to the gravitational pull of the earth. An object accelerating at say 1.5g would require a restraining force of 1.5 times its weight. If an object is subjected to a force 1.5 times its weight, it is said to be under a 1.5g load condition. A motorcycle coming down from a 5 foot high jump takes about 1/2 second to hit the ground and in that time it has reached a vertical speed of 16 feet per second. Now if it takes 1/10 second to reduce the vertical speed to zero, then the bike has been accelerated (or decelerated) at 160 feet per second per second or 5g. Every part on the bike and all the attachments have been subjected to a load equivalent to 5 times their weights for a period of 1/10 second. In some instances this can be considered a shock load especially when something breaks loose. If everything has been designed to withstand this kind of loading, then it is considered normal. If the bike is repeatedly subjected to loads of this nature, then fatigue must be taken into consideration and everything beefed up further.

External 'g' loads are of course seen by the engine at frame attachment points and at the attach points of accessories such as the carburetor and exhaust pipe. The most critical external engine loads are those transmitted through the drive train to the points of attachment such as engine mounts. Rapid clutch engagements, gear shifts or the sudden discovery of traction by a spinning wheel can put tremendous loads on the chassis.

If you were able to wade through that you're ready to dive into design and construction priciples. Periodic cleaning and inspection for these hairline fractures, particularly at welds and junctions, will permit you to repair and arrest a dangerous failure. This is about all you can do, inspect and weld. In some cases reinforcing the frame superstructure or beefing up a swing arm will save you a lot of future grief. Frame breakage and failure isn't prevalant

CHASSIS DESIGN

with most modern motorcycles, but it isn't uncommon either. Don't discount it happening to you. Understanding the construction and design of frames may help you forsee some of the enourmous problems of trying to engineer the perfect chassis.

As with every other component in the motorcycle, frames have undergone considerable evolutionary development over the years. Today, manufacturers are using three types of frame design for production. Each has its own advantages and disadvantages. There are the single and double loop cradle tubular frame, monocoque and backbone styles. By a wide margin, the welded tubular steel type is the most commonly employed.

European and British manufacturers have always emphasized the value of frame design and good handling qualities over engine performance. This has been proven again and again in just about every class of street and competition bike.

No matter what type of frame design comes under discussion, one of the primary factors surrounding its worth (or worthlessness) is its rigidity. In the tubular frame, double and single loop, rigidity is ensured via *trianglization.* The tubes are curved in such a manner, that when welded together, they form a group of triangles concentrating the stress points at the corners. Stresses therefore act upon three points rather than one. An excellent example of this layout on a modern bike would be the triangle formed by the upper rear shock absorber mount, rear axle and swing arm pivot.

Monocoque frames are widely used in various classes of racing cars, but in production motorcycles, their application has been limited to some of the small-displacement Japanese machines. Notables are the Honda 90 and Yamaha 80. Monocoque bike frames are formed of stamped sections welded together at matched seams. They are tremendously strong, can be manufactured by unskilled manpower and lend themselves to mass production quite well. However, they are quite heavy for their size and do not lend themselves to production changes easily.

Banana and backbone type chassis are widely applied by European manufacturers, and while they use steel tubing, they are laid out in a completely different manner than the cradle frame. Backbone frames utilize a large-diameter tube originating at the headstock which runs horizontally back to the fuel tank area, then curves downward behind the engine/transmission area. The engine is attached to the tube in several places, forming a stressed component.

Similar to the above is the banana type frame. It uses no support from the steering head to the engine, as with the backbone type. Support is drawn from a formed section which curves downward to the center of the bike, then sweeps back up to the rear. Sections of tubing originating from this primary member support the rear suspension and powerplant. Certain examples of this variety use the powerplant as a stressed member, others do not.

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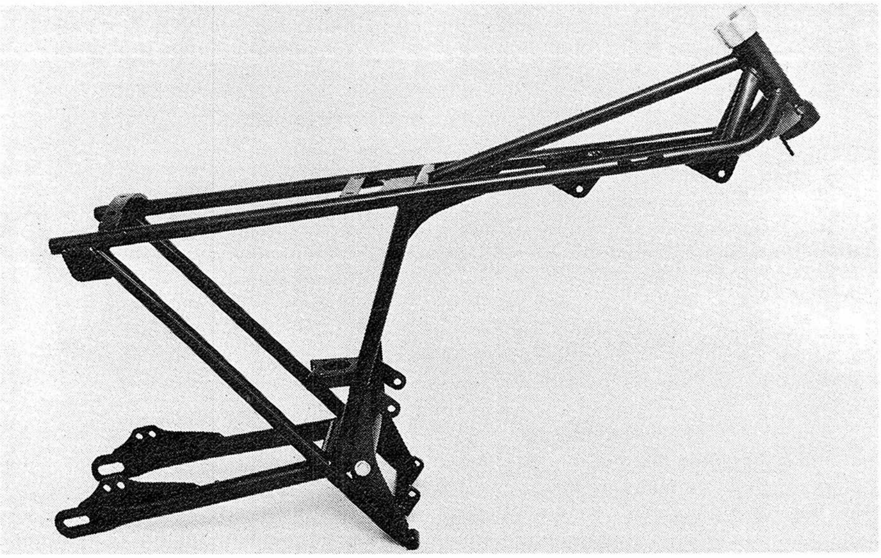

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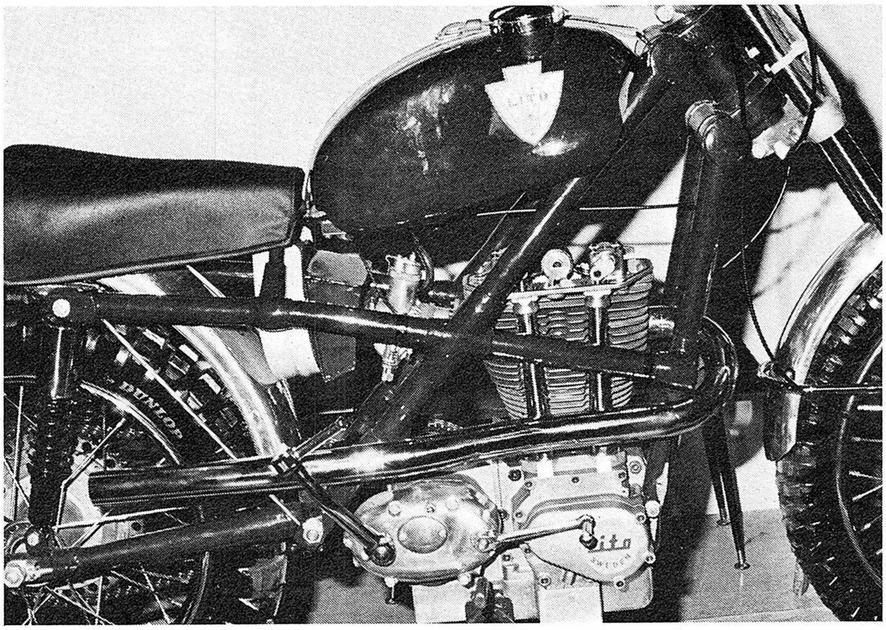

1. This unusual multi-tube backbone type frame uses engine as a structural supporting member where attached under headstock, forward swing arm.

2. One of the most incredible frame designs we have ever seen is this Swedish Lito scrambler. Huge thinwall tubing is joined by special castings.

Aside from the front and rear suspension, a motorcycle's handling characteristics are governed by the location of the engine, seat, foot pegs, steering head angle, swing arm location and length. Collectively, all these components have a relation to each other in weight distribution and center of gravity.

The center of gravity (CG) is the point on any bike where it would spin like a top if a rod were passed through that point horizontally. CG is controlled by the bias of weight

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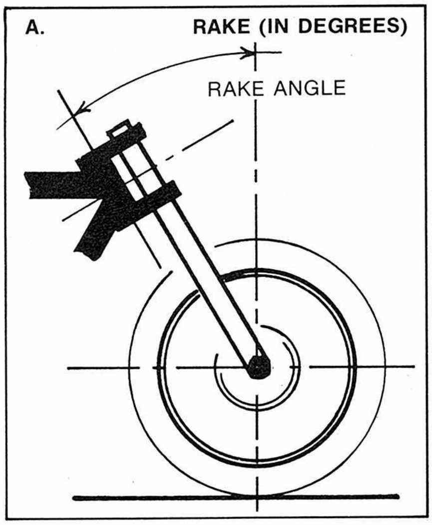

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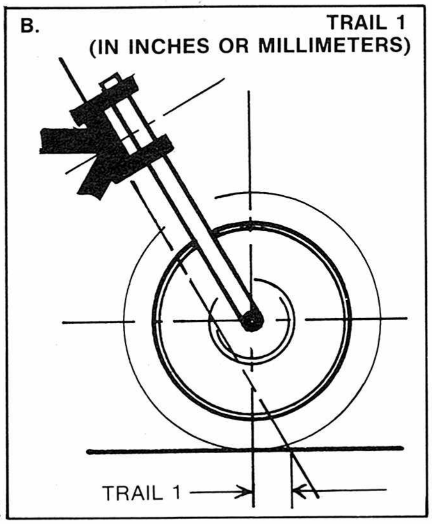

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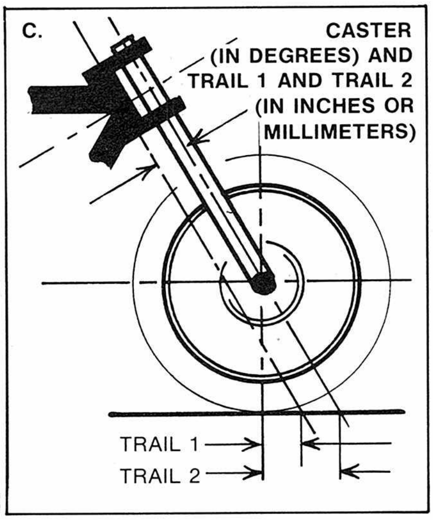

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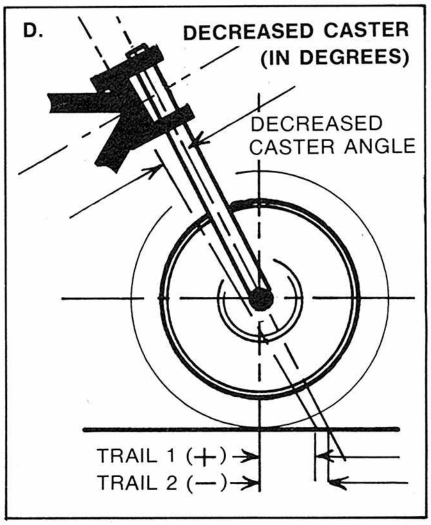

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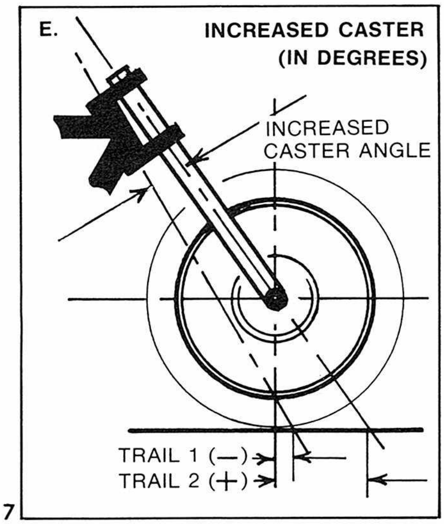

3. Initial figure relating to front steering geometry is rake angle (in degrees). This is measured from the headstock center line to a vertical drawn from the CL of the front axle.

4. Next is a horizontal measurement, trail, calculated by running the headstock centerline to ground level, dropping the vertical axle CL straight down then measuring the linear distance.

5. Caster is the amount of angular difference the fork legs may be from CL of the headstock. In most cases this figure is zero or parallel centerlines.

6. Negative caster angle will produce two trail measurements from verical of the front axle, one from the fork angle the other from headstock CL.

7. Increased caster can often produce excessive negative trail (1) and better tracking but unstable turning.

supported by each wheel, and the distribution of the locations of masses (engine, oil tank, etc.) from top to bottom of the machine. Relationships between these two factors determine a bike's general handling characteristics.

Most modern bikes have a weight bias varying from 45 percent front, 55 percent rear, to 40 percent front, 60 percent rear. The first set of figures applies to the typical street and road motorcycle, while off-road and moto-cross machinery will be in the 43 percent front, 57 percent rear category. Reasons for this: Road bikes have more components, higher total weight with most of it located towards the front. Dirt bikes have fewer components and lower total weight. The off-road machine performs better when there is close to 15 percent less weight on the front wheel than on the rear, while the road-goer handles better with a more closely equalized bias and central CG. In terms of weight, these figures could mean 10 to 20 pounds (more or less) on the front wheel.

The center of gravity should be as low as practicality permits. In other words, engine, seat and footpegs should be located as near to ground level as possible. This means that the machine will tend to remain vertically stable. Two exceptions to this rule are trials machines where the rider moves at very low speeds and is turning and leaning constantly to avoid obstructions—and dragster/Bonneville machines which need to travel in a straight line only. The trials machines have a higher than normal CG, while the quarter-miles and record breaks need an extremely low CG.

Let's stick to the conventional motorcycles in this discussion. Naturally, different machines, even in the same class have different CG's, so we must use a common, easily located point to determine the vertical center of gravity. This point will be the centerline of the crankshaft. On most modern road machines, the crankshaft's centerline should be common with, or no more than one inch higher than the centerline between the front and rear axles. In this case, we are referring to bikes above 100cc displacement and/or 200 pounds in weight. A higher crankshaft centerline would lead to top heaviness, while a lower centerline could cause ground clearance problems when cornering. The greater width of the three- and four-cylinder engines makes this problem more acute.

Taller four-stroke engines usually have the CL of the crankshaft overlapping the horizontal axle line. Examples are the Triumph, BSA, Norton and other European road bikes, all of which are considered to be good handlers. Some of the best handling machines of all time were four-stroke singles such as the Velocette, BSA Goldstar and Matchless. Because of the height and narrowness of these designs, their crank CL's were usually below the axle CL—up to two inches below.

Current Japanese practice keeps the crankshaft CL as much as three

inches above the centerline of the axle. This has resulted in top heaviness, mostly in road bikes. It shows up in cornering and at high speeds. Much of the Japanese machinery has a higher weight distribution on the front wheel than British and European bikes.

Small displacement, light weight trail bikes are an exception to the above situation. Their crankshaft CL's are as much as two inches above the axle CL. Handling is not adversely affected due to the fact that these small bikes have CG's in about the same region as larger types. Furthermore, these bikes are not subjected to the high stresses and speeds of other machines.

Now let's discuss another factor that determines CG: Footpeg and saddle position. Naturally, the center of gravity will change with the rider(s) aboard. With a road bike, saddle location plays a very important role here. Footpegs account for only a small portion of CG change, but obviously the rider's weight is concentrated almost entirely on the saddle. Time has proven that the optimum saddle height above ground level is 31 inches. Road racers will sometimes lower their height to as low as 28 inches for improved handling, but any height above 31 inches will adversely affect handling due to an elevated CG.

Saddle height is of secondary importance on the off-road bike. In this case, footpeg position assumes the critical role, the reason being that the rider's weight will center on the pegs when he stands upright. This is especially critical on motocross machinery. Saddle height is still important, though, on other types of dirt bikes, because more time is spent sitting than standing.

Trail bikes are an exception. Here there are no requirements for high-speeds or cornering. These machines must be extremely agile at low speeds, therefore they have high engine and footpeg location for extra ground clearance. The footpegs are above the crankshaft's CL and behind the engine and gearbox. This results in maximum weight distribution on the rear wheel.

Now, let's put some of these components together, beginning at the front and working rearward.

First, the fork assembly must be attached to the chassis head stock. The primary consideration at this point is the rake (see drawing 'A'). This is the angle in degrees between the vertical CL of the front axle and CL of the head stock.

This angle does *not* always indicate the angle of the forks themselves. True fork angle can vary if upper and lower triple lamps are not identical, but for the moment, assume that fork angle and rake are identical.

Current road bikes have a rake angle of 26 to 28 degrees. Some Japanese machines are nearer the 26 degree figure, while European and especially British bikes are closer to 28 degrees. On =off road motorcycles and moto-crossers have slightly more rake angle, usually between 28° and 30°.

The other front end dimension which must be determined is *trail* (see drawing 'B'). Trail is the horizontal distance (in inches or millimeters) between the vertical axle centerline (CL) and CL of the head stock. Trail measurements range from 2½ to four inches. Road bikes will be closer to three inches, while off-road machines will be closer to four.

Trail is the most critical measurement in regard to the front end because it determines to a large degree how the front end performs. The greater the trail, the more the front end will "trail" or go in a straight line. The machine with the

1. The brothers Rickman set a new standard in competition and specialty chassis design with their nickel-plated scrambler frames and wheels.

2 One-off frames are commonplace with diggers. Monstrous tubing gives rigidity to lengthly wheelbase. Rake, trail and wheelbase keep this twin Triumph going in straight line.

3. Specialty road racing chassis also one off. Features light weight with maximum strength. Welding is heliarc.

4. Britisher Alf Hagon specializes in dragster chassis for big 'V' twins. Uses backbone idea with engine as supporting member; minimal welding.

5. Location of center of gravity moves with any change of front or rear wheel position. Location changes logitudinally, not in height.

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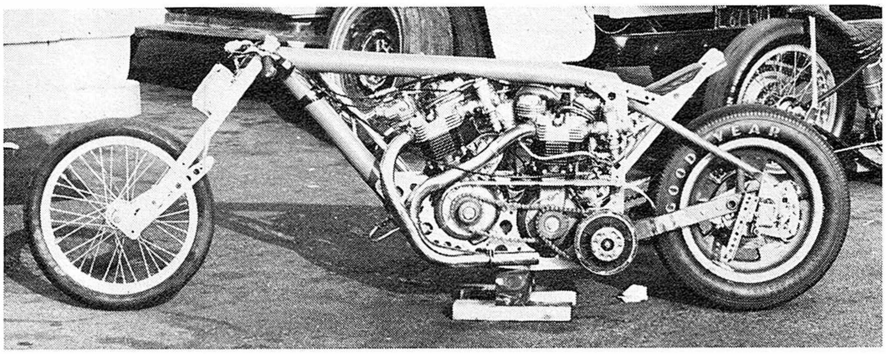

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most trail will have the greatest steering effort. Examples of extreme trail would be four inches in a dragster or Bonneville machine and 2½ inches or less in a trail bike.

There is a second method of finding out the trail of forks. This is measured by finding out the horizontal distance between the centerline of the forks and the vertical line used in the previous trail measurement. This method is used when the upper and lower triple clamps are of unequal, the forks will not be parallel with the head stock CL.

As you can see in drawing C we now have two trail figures, #1 and #2. Trail #1 is the relationship of the frame head stock angle to the chassis and is directly derived from *rake angle.* Our new figure, Trail #2 is the relationship of the front fork assembly to the head stock. And this brings up another new figure, *castor angle* which is the angular difference of the fork assembly to the headstock.

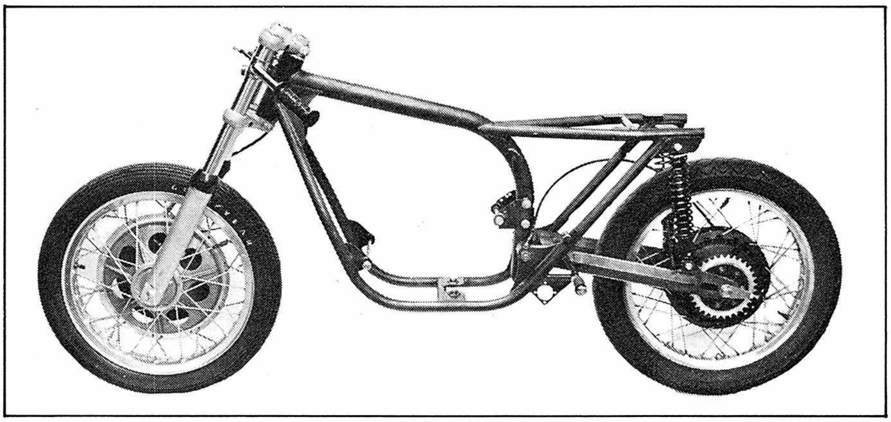
As shown in drawing C, 0 (zero) degrees castor angle is when the fork assembly is actually parallel to the head stock. Most manufacturers use this 0 degree figure as standard by making the top and bottom triple clamps identical. Having 0 degree castor angle insures a constant relationship of trail #1 to Trail #2. This will tell a rider that oversteering or understeering difficulties will be related to *rake angle* and the chassis head stock as the *caster angle* is 0 degrees.

In drawing D you can see the physical results of having a decreased castor angle. This occurs when the lower triple clamp is shorter than the top and pulls the front wheel axle to the rear. The result is an increase in Trail #1, but a decrease in Trail #2. The effect here is to let the front wheel trail or track more than 0 degree castor angle while greatly increasing the steering quickness. Most complete Ceriani fork assemblies come with non-matching upper and lower triple clamps that give a resultant decreased castor angle around one degree. Decreased castor angle would tend to neutralize an understeering condition.

Now, conversely in drawing E we see increased castor angle and the technical results. Increased castor angle-results in a sharp decrease in our Trail #1 figure while stretching out the Trail #2 dimension. Some of the veteran cross country riders used to install what is called a *rake plate* (actually a misnomer, should be a castor plate) to get more fork angle and slow down the steering. While this slowed down the steering it had a pronounced result in making turning sharply side-to-side more instable if the castor angle increased more than two degrees. But some production machines have found a slight bit of increased castor angle was good to slow the steering feel on road bikes. Triumph used 0.48 increased castor angle for many years with their 30.5 and 40 cu. in. road burners.

Rear suspension is equally important in handling as the front, but less complicated. Today, the swing arm coupled with spring-over-shock is almost universal in motorcycle engineering. Angles, dimensions and fixing locations have seemingly become nearly standardized throughout the industry.

The swing arm is pivoted at the rear of the frame and its pivot center shoud be ½- to one inch above the horizontal CL of the rear axle and countershaft sprocket. This permits chain clearance when the



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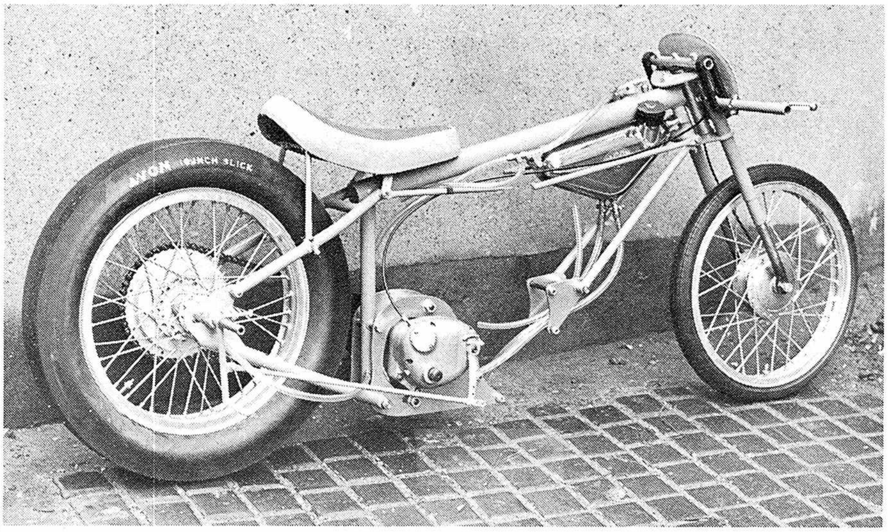

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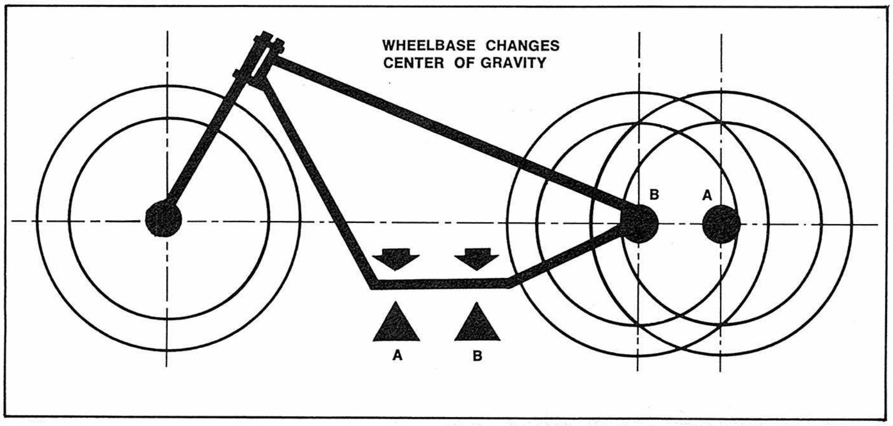

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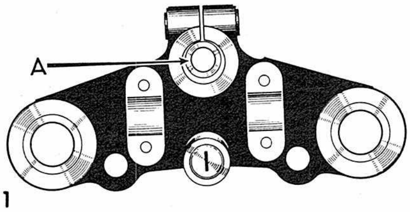
suspension is fully compressed upwards.

With the machine at rest, the swing arm should be parallel (see drawing 'F'), or nearly parallel to the ground. When the swing arm angle is correct, the rear wheel is pushed directly upward into the shock absorber when encountering a bump. If the swing arm angle is excessive (see drawing 'G'), however, the rear wheel will be pushed rearwards as well as upwards and the shocks are unable to absorb the full force. The remainder of the force is directed forward to the swing arm pivot, and from there to the frame.

Finally, we must determine the length of the swing arm. This measurement is taken from the CL of the swing arm's pivot and the CL of the rear axle. Here again, we find a common figure near 18 inches. Common exceptions are trail bikes with swing arms nearer to 16 inches and hill climber that can run to 22 inches. The short swing arm causes more weight to be placed on the rear wheel, while the longer arm on



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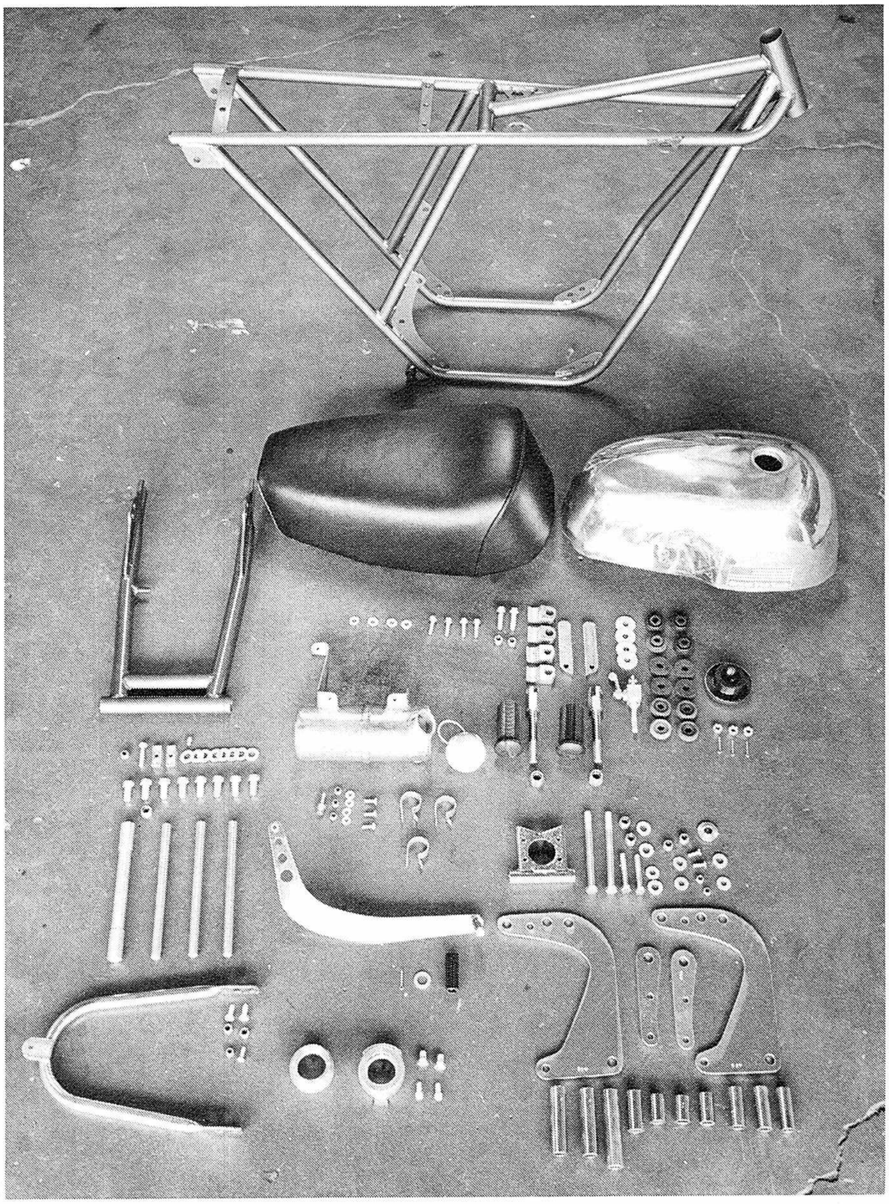

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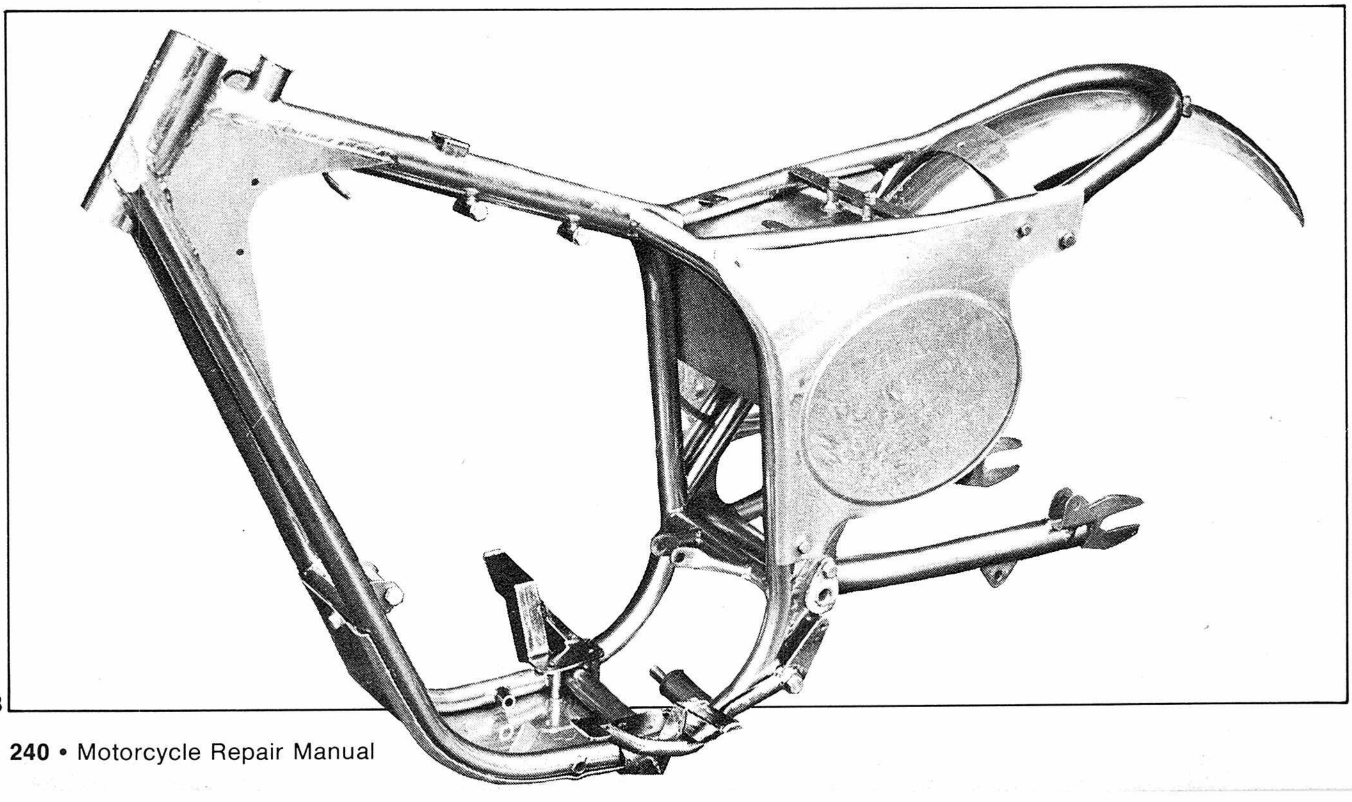

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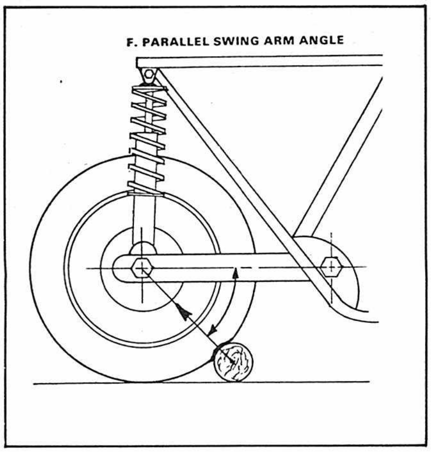

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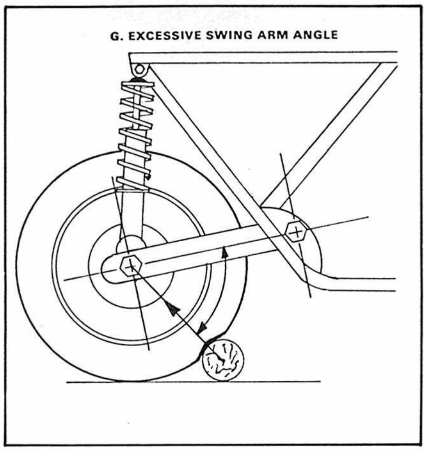

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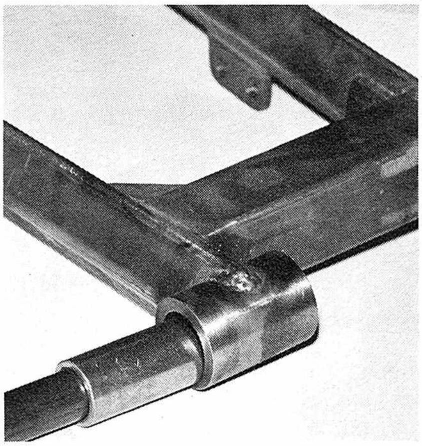

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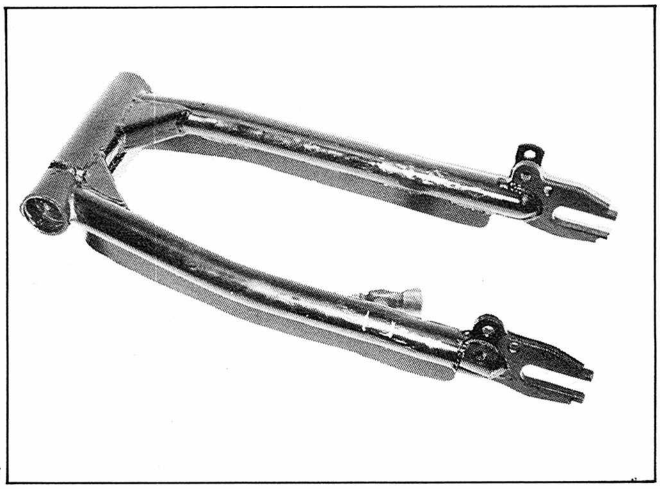

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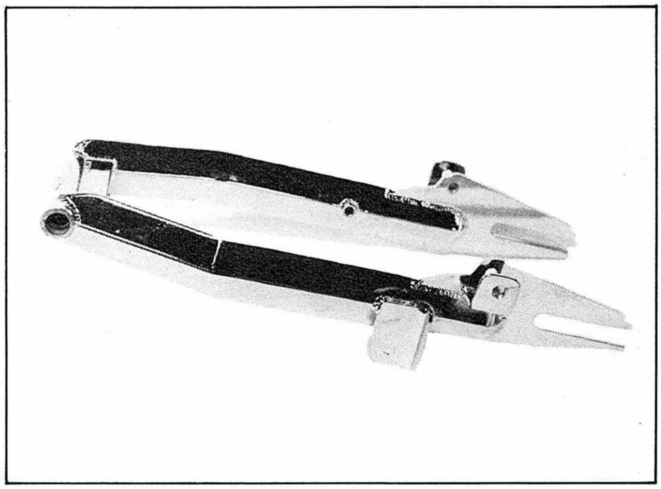

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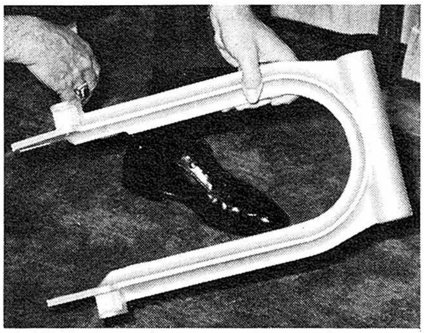

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1. Some machines, particularly British, use offset (non-identical) triple clamps. Object is to decrease caster angle about ½ degree to quicken steering with minimal harm to trail.

2. Complete specialty chassis kit has all parts less wheels and engine.

3. Rickman moto-cross chassis for four stroke has abundant headstock gusseting. Was one of first bikes to use the tubular chassis members as oil reservoir. Had large capacity, ran cool.

4. Preferred to insure least shock and best pivot angle is swing arm parallel to ground level. Also forces chassis height to be lower to ground.

5. Excess swing arm angle is common with many Oriental machines. Swing arm arm angle places greater shock load on pivot point and axle. Thrust of force makes shock absorber task more difficult and demanding.

6. Best for swing arm pivot point is Oilite bronze bushing between tube steel members with shaft in middle. Oilite gives good lube, minimum flex.

7,8,9. Different needs make for different ideas. Most common is round tube swing arm. Has low material and production cost and provides adequate rigidity. This one has been strengthened with flat steel supports, bottom. Rectangular swing arm is said to be strongest for side thrust loads. Material more costly, hard to bend. Cast aluminum fork offers light weight and low cost in mass production. Still in testing stage, this cast idea may provide progressive step forward.

hill climbers is to cause the opposite effect—as much weight as possible on the front wheel.

What we have covered in this section on chassis is not as much theory as experience acquired over many years of practical application and study of motorcycle frame design. Sure, there are exceptions to every rule or practice mentioned and there always will be. The three undetermined factors that determine what combination works best is engine size, rider (size and style) and environment or how the machine is to be used. As it goes today chassis design has reached a point of near perfection. Look at the Yamaha Enduro line that uses the same chassis style for all its machines, but considerable improvement was seen with the introduction of their special production motocross chassis. Honda's four cylinder bikes have all but identical chassis design, power to weight ratios and suspension units. Yet the 500cc four cylinder model is heads above the other models in handling performance. Why? Was the 500 designed to handle better intentionally? Probably not, it just happened that everything fell together in better proportion.

While we never will be able to completely understand all the relationships of chassis design to handling characteristics, we do have the basics. Some of these cannot be deviated from and become constants. Therefore, the variables such as rake and trail and castor can be studied further to offer a solution to a handling problem. Surely after reading this you will place more emphasis on studying those spec charts when reading road tests or listening to the local racers talk. Now it isn't all Chinese and can have some absolute value to you which is much more than most motorcyclists can enjoy.

METAL TREATING

From 'A' for Anodizing to 'Z' for Zyglo, here's the lowdown on these engineering life savers

BY DALE BOLLER

Everyone knows about chrome. It's an electroplating process involving a lot of immersions in bubbling and pungent liquids and a lot of polishing on special buffing wheels treated with rouge—a compound having the same name as the stuff that makes your mum's cheeks red, which is why you remembered its name. Decorative chrome is used for appearance, is expensive, readily available and tougher than most surfaces but requires steady attention to remain lustrous. We all know about chrome because our bikes come loaded with it from the factory.

But what about other metal treating processes you've heard of, perhaps revered, yet know little or nothing about in reference to your day to day motorcycling? Anodizing, nitriding, vapor honing, heat treating, cold stabilizing, hard chrome, shot peening, stress relieving, Mar Tuffing, Tufftride, or the testing methods of Magnaflux and Zyglo. That's a whole bunch. And they're all important to us in one way or another. Some are only of marginal benefit to the average rider, but an overview of what processes are available will be helpful should you wish to get serious with a racer or cure a persistent problem in a particular street machine.

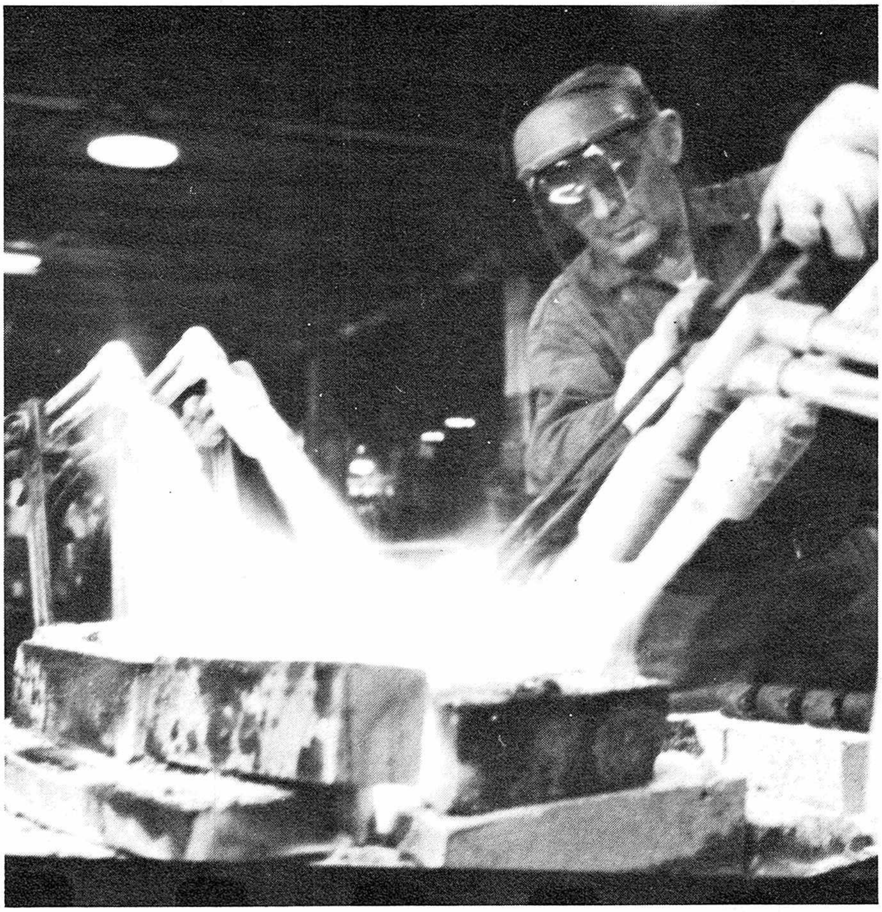
This article is an introduction only, and in all cases the actual consultation and work should be done by established experts with proper facilities. Because the processes actually work, there are many such facilities across the country. Ask the top tuners in your area—they know who to contact and which processes to use on what parts; otherwise they wouldn't be at the top. These techniques are that important. For instance Magnafluxing can detect a tiny crack in the surface of metal which could lead to premature fatigue failure. Anodizing aluminum will prevent corrosion from the elements, even if you live at the beach. Shot peening a crankshaft will increase its effective life by 900 percent, connecting rod by 1000 percent and a valve spring by 1370 percent. That last percentage goes for shock and fork springs too. There's a lot more to say, but let's delve into the processes one at a time.

MAGNAFLUX & ZYGLO

Our discussion will begin with nondestructive metal testing (NDT) by Magnaflux and Zyglo systems, because that's where every mechanic should begin prior to assembly of an engine from new or used parts. Magnafluxing detects surface cracks in ferrous metal (that which will attract a magnet) and Zyglo locates cracks in nonferrous metal such as aluminum or magnesium. Detecting these cracks is important because they can lead to fatigue failure, which is breakage of the part as stresses of reciprocation or torque promote a spreading of the crack until eventual failure results. Most all metal failures can be traced to premature breakage beginning with tiny surface cracks invisible even in a detailed visual inspection.

Realize and never forget that 90 percent of the stress flow on a component occurs on the outside 10 percent of its volume, which simply means maximum strain from any loading is on surface molecules. This metallurgical phenomenon is why most all metal treating processes involve treatment to a very low depth yet are still extremely effective. This is why Magnaflux, though dealing with external and extremely shallow subsurface deficiencies exclusively, is the only test necessary on most highly stressed parts. More expensive X-ray techniques which reveal internal structural flaws have minimal use outside of critical aerospace applications, and failure resulting from internal defects is rarely a problem for motorcyclists.

How do these detrimental external cracks occur? Some are induced in manufacture by improper milling, bending, grinding, casting, plating, heat treating or handling—this is why



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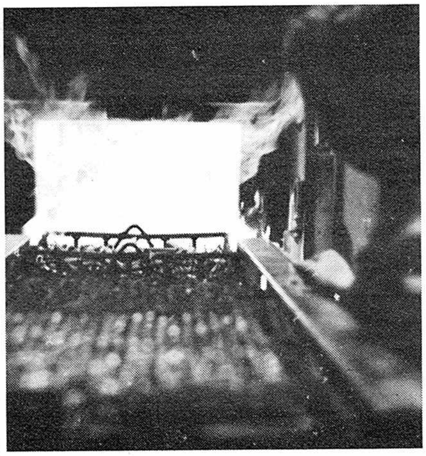
HEAT TREAT

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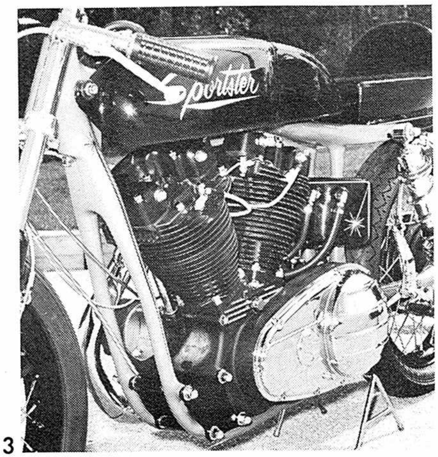

ANODIZE

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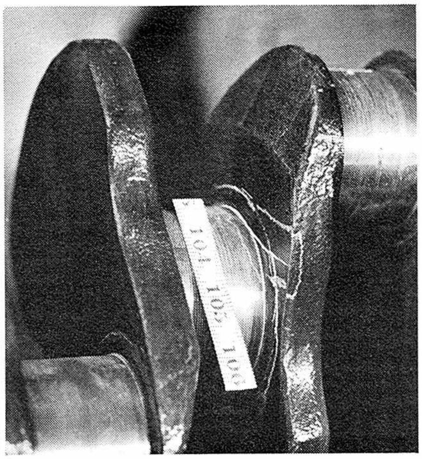
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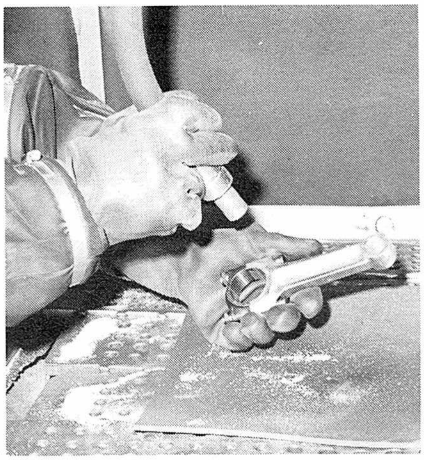

SHOT PEEN

1. Hot stuff. This skilled worker at the Harley Davidson factory is blast brazing malable-iron frame castings to join with medium-tensile tubing.

2. Hardening of gears and like parts is done in this carburizing gas furnace at 1700°. They are then quenched in a 300° oil bath for hardness.

3. This Florida-based Sportster shows how black anodizing aluminum parts can dress up a machine while offering superb corrosion resistance. Anodized engine and hub also cools better.

4. Magnaglo particles shine as white line along crack's path. Its location is outlined with chalk for customer to see. This is an automotive crank with motorcycle characteristics.

5. Shot peening is a simple process which increases the life of parts by several hundred percent. Peening is just a matter of air blasting a part like this Triumph rod with glass beads to hamper fatigue.

all new parts should be Magnafluxed before use. Corrosion can cause cracks in metal that is under tension or stress because it weakens grain boundaries in metal. Areas exposed to abrasion without proper lubrication can gall or fret, with resultant scratching that leads to cracks. But by far the most common cause of cracks is fatigue of the metal from the stresses of service. In normal use stress reversals and variations are always causing minimal fatigue, but usually the stresses that initiate fatigue cracks are *over*stresses caused in several ways: vibration (often excessive in motorcycles), accident, handling a load different from that for which the part was designed or abuse of the motorcycle through overrevving, wheelies, speed shifts or the necessary rigors of racing.

Metals fail progressively, not without warning through internal crystallization as formerly believed. Engineering studies have shown that the first sign of a fatigue failure is the formation of small incipient cracks which gradually develop into larger flaws and result in eventual failure if the part is left in service. In short, metals most often fail because of cracks; therefore it is imperative to detect these invisible enemies by nondestructive metal testing before they cause in-service breakage.

Magnaflux Corp. pioneered NDT in 1929 when its cofounders, a physicist and chemical engineer, discovered they could test metals without damaging them in any way by using principles of magnetism. "Magnaflux" is actually a registered trade name which, like Coke and Scotch Tape, has become synonymous with the company's product—nondestructive metal testing equipment.

Technically, Magnaflux and Zyglo are quite simple. In "magnetic particle testing" (Magnaflux) a magnetic field is set up electrically within the part; when fine iron oxide particles are blown (dry method) or flowed in liquid suspension (wet method) on the part, they are attracted to the crack and form a definite indication of its exact location, extent and shape. This is because the lips of the crack break the magnetic flux and each side of the crack becomes a magnetic pole capable of attracting particle iron. If the particles are treated with a fluorescent coating, cracks stand out under ultraviolet light like a neon sign and the process is called Magnaglo.

Any component which cannot be magnetized must be checked with Zyglo, another trade name of the Magnaflux Corporation's version of "fluorescent penetrant testing." Aluminum alloy pistons, heads, cases, rods, motor mounts, etc., fall into this category. Zyglo relies on the capillary action of liquid to penetrate defects in any nonmagnetic solid. The piece is dipped in fluorescent penetrant, rinsed, dried, a developer applied which draws penetrant within cracks to the surface and finally inspected under black light where cracks glow with startling clarity.

Usually a part is scrapped if it "fails Magnaflux," i.e. if cracks are found. But not always; some seams running parallel to stresses are relatively harmless and certain surface cracks can be ground and welded so the part is as strong as new.

Where can you have something Magnafluxed? The Magnaflux Corp. has testing centers in 13 cities around the country and there are hundreds of certified inspection stations in aircraft and automotive overhaul garages. Check the Yellow Pages or the United States Auto Club, which has a listing of approved Magnaflux stations in your area.

What parts should be Magnafluxed (or Zygloed)? On motorcycles, engine parts are most critical. Must items are crankshaft, rods, wrist pins, rod bolts, cam, rocker arms, valves, gears, pistons and transmission shafts. On the chassis check triple crown, axles, swing-arm shafts, hubs, motor mounts and bolts for fork caps and shocks.

How often? As often as possible. At

METAL TREATING

Indy 31 checks are made on each car several times during practice and qualifying and prior to the 500. Magnaflux has been at the track since 1936. Bucks-up builders and racers can't risk failure at the brickyard because of the huge prize money and speeds at stake. Yet stresses in a long desert race, grueling motocross or top-fuel digfest often surpass those at Indy, so take a tip from the money boys and Magnaflux every time your bike is apart. It all boils down to how much you value your engine, and your life.

Any special preparations for testing? Parts should be purged of all dirt, grease and baked-on carbon by thorough cleansing in solvent or by a blast of cleaning abrasive such as glass beads or crushed walnut shells. Cracks can't be detected if covered by another component, so dismantle all parts and separate ferrous from nonferrous pieces. Most Magnaflux stations are accustomed to dealing with balanced component systems and won't mix things up if they're properly tagged. Don't identify parts by punch marking because this often places unwanted surface stresses on the part. Be sure the station you select can demagnetize parts after completion of inspection.

How much? Testing costs range from a usual minimum of $5.00 for a few pieces to around $15.00 for all engine parts and critical chassis components. If the price and effort involved seems high, think of Magnaflux as insurance against breakage. Everytime you find a crack, you're collecting on your insurance.

Preventing these cracks is the function of many of the other metal treating processes—shot peening, nitriding and Tufftriding in particular.

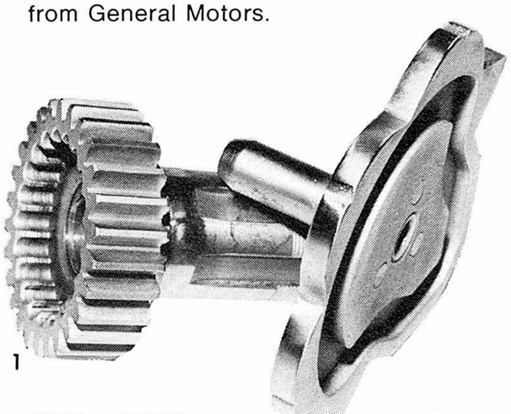
SHOT PEENING

Peening was discovered and used by the sword makers of the Middle Ages. Today's shot peening is a precise and scientific extension of this ancient art—it is a method of inducing uniform compressive stresses on the exposed surface layers of metal parts by the impact of small diameter glass or steel beads. Compressive surface stresses hamper the formation of fatigue cracks which lead to failure of highly loaded parts. When a bead impacts metal, it forms a tiny crater, compressing surface molecules under its circumference. Bombardment of the whole piece by thousands of beads eventually leaves the entire surface in a tightly packed state highly resistent to subsurface cracks escaping or surface cracks forming. This is because a greater force or longer time is now required to pull the material apart.

A second advantage of shot peening is that it can cancel uneven surface stresses left from machining, mechanical forming, plating or polishing by inducing a greater uniform stress of its own.

Highly skilled technicians must determine from a number of variables what exposure time, rate of impact and size and type of bead is best for your particular part. Results are staggering. Tri-Process Co. in Paramount, Calif., a peening firm with many aerospace contracts and two technicians with 25 and 15 years experience respectively, claim the following fatigue-life improvement percentages: Cranks, 900 percent; rods, 1000 percent; coil springs, 1370 percent; and rocker arms, 1400 percent. Bob Gorsuch of Excello Plating in Los Angeles provides Magnaflux, peening and hard chrome services for Eddie Mulder, Gene Romero, C. R. Axtell and others and offers more tangible findings. He says a stock Triumph crankshaft will last seven to eight race meets before failing Magnaflux or breaking; a shot peened crank is healthy for 15 to 18 torture sessions. Super hard riding by Gene Romero makes him an executioner of engines, but he's never broken a shot-peened rod. Think what peening can do for the stock machine and average rider! A variety of both aluminum and steel parts will benefit—head, cylinder and case castings, cranks, rods, valve stems, rockers, valve springs, fork springs, transmission shafts and shifter plates—most anything subject to high dynamic loading or variations in stress. But be sure your source knows what he's doing for adverse ramifications are so detrimental that peening specifications for aerospace take up several volumes—it's a real science.

Here's how valuable General Motors thinks it is. The man who really perfected the procedure back in the Thirties was a GM researcher named John Alman, who was working on a way to increase valve spring life. Months of different heat treating processes brought no results until one day a certain spring suddenly doubled its performance on the testing machine despite no known change in treating methods. Alman interrogated every man who had handled the spring and learned this particular spring had a little extra heat-treat scale which was removed with an abrasive blast. You can guess the rest. Today Alman is in his 70's, living in retirement in Sierra Madre, Calif. Every year he receives a new Cadillac from General Motors.



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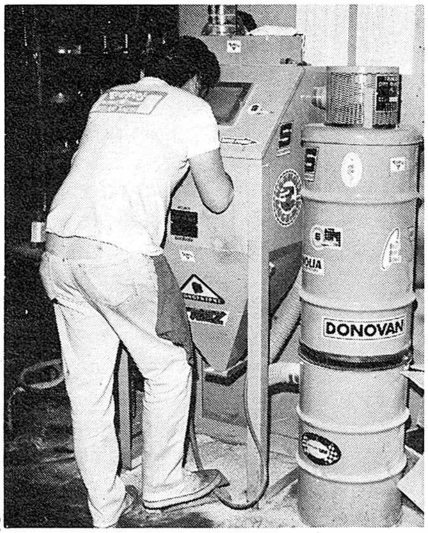
HARD CHROME



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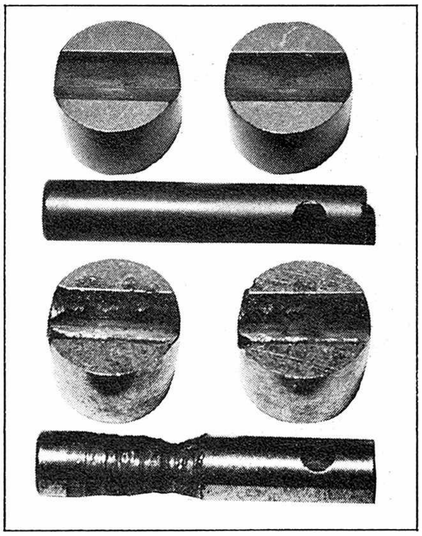
DRY BLAST CLEANING



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DRY FILM LUBRICANTS

NITRIDING

Nitriding is the long-established practice of hardening the outside surface (casing, therefore "case hardening") of metal to a depth of .015-.030-inch to increase wear and fatigue resistance. During the sealed furnace process, nitrogen is absorbed from an atmospheric environment of ammonia or methane gas heated to 975° and subsequently diffused into the base metal, leaving the case (surface) quite hard and more able to resist galling and wear. Also, because the case becomes more dense and slightly expanded in volume as a result of nitride formation, surface layers often inherit high compressive stresses which aid fatigue life. One drawback is the formation of Fe_2N, which tends to be brittle. Minor disadvantages in nitriding are a long process time of from 10 to 50 hours, slight loss of ductility in the part and the requirement that the part be made of high-alloy steel, free of nickel. Cams and cranks are the most often nitrided parts, at a cost of $15.00 to $20.00 from most heat treating services.

TUFFTRIDING

German metallurgists developed Tufftriding in the late 1950's, and the process is now licensed in America by the Kolene Corp. in Detroit. It's a case conditioning technique in the nitriding family, but more flexible in that treatment times are much shorter. Low carbon steels may be processed and brittleness is reduced considerably. Additionally, Tufftriding can be performed *after* finish machining and heat treating, and a part is ready to use immediately except where bearing surfaces must be micro-polished, as on crankshaft journals. A Tufftrided surface has greatly improved anti-galling and non-seizing qualities. Corrosion is curtailed to the point that Tufftrided fasteners need not be cadmium plated.

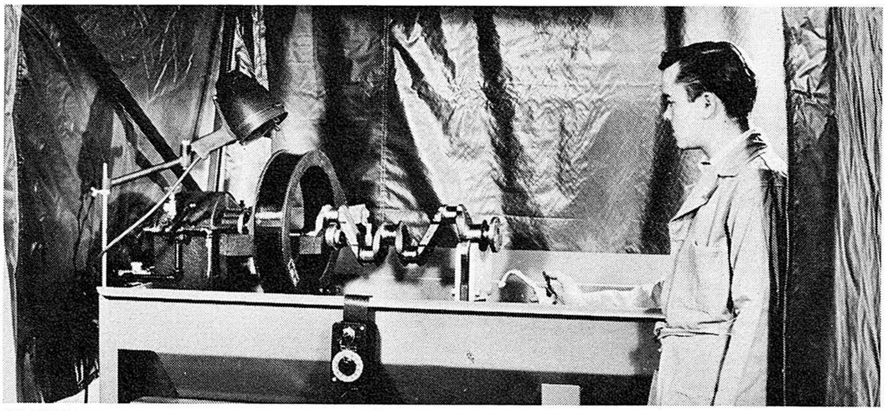
The actual process embeds carbon and nitrogen into surface molecules thereby adding toughness and compression to the casing. Notice we didn't say "hardness;" unlike nitriding which increases wear qualities by greatly hardening the surface, Tufftride's completely different (and patented) chemical process adds only minimal hardness, but instead forms a surface compound zone of "carbon-bearing epsilion iron nitride," the tough, yet ductile iron nitride and carbide molecules responsible for nearly all the benefits of the process. Parts are immersed in a 1060° molten salt bath consisting mostly of potassium cyanide and cyanate which break up into carbon, nitrogen and oxygen atoms. Since nitrogen is 10 times more soluble in metal than carbon, large quantities quickly diffuse .010-.020-inch into the surface, adding volume and density as in nitriding and thereby forming a compressive stress beneficial to fatigue resistance. Slower diffusing carbon atoms then join the outermost concentrations of nitrogen to form a .0003-.0004-inch wear-resistant outside layer of the iron nitrides Fe_3N and fe_4N and iron carbide Fe_3C, with no brittle Fe_2N. Time for the magic crust to compose—one to two hours, depending on the alloy.

More parts may be Tufftrided than nitrided. A wide variety of engine components may receive the benefits of a Tufftride structure. Cams, cranks, rockers, valves, piston rings, cylinder liners and even clutch plates can be given up to 350 percent more life in terms of normal wear and up to 80 percent more fatigue resistance. To the racer these figures are a godsend because stresses are always more than the parts were designed to withstand. To the street rider who likes his particular bike a few parts treated at the time of first overhaul will extend the duration to the next and provide considerable peace of mind. The usual minimum charge of $12.00 to $15.00 will cover a crank and cam, with other parts included at $.20 per pound additional.

Any persistent problem such as clutch slippage or sprocket wear may be improved with case hardening experiments. But don't run down to your local Tufftrider with a chain—it's a high alloy steel already hardened by the manufacturer, and in such cases "Tuff Stuff" could have a softening effect.

MAR TUFFING

Here's a brief preview on what is a significant breakthrough in metal treating technology. Mar Tuff heat treating techniques evolved beyond established procedures in an effort to extend gear life on the devastating top fuel dragsters and was developed by Pepe Estrada of Pepe's Rear Ends in Paramount, Calif., a willing and helpful consultant on this article. The process involves carefully monitored exposure of gears and other hardened steel parts to refrigeration, tempering and atomic radiation, all of which are aimed at establishing uni-



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MAGNAFLUX

1. Hard chroming doesn't increase performance, but it does decrease wear and fatigue. Hard chrome on a Triumph gear and shifter cam plate is hardly noticeable, but adds significantly to arrest wear. Edge of cam plate is polished to further reduce friction and often drag racers will polish gear teeth also.

2. Dry blast cabinet units for sand or glass bead cleaning are compact but need a large air compressor to maintain constant operating pressures. Dust is sucked by blower and stored in drums at right. Abrasives funnel to cabinet's bottom and recirculate. Multitudes of blasting materials are available like glass beads, steel particles, various sand types and even aluminum. Material sizes also vary.

3. The potential of solid dry film lubricants is clear from this demonstration. Both shafts were compressed between the notched buttons at 1000 psi and rotated at 300 RPM in a bath of oil for 15 minutes. Top pieces were treated with Everlube, show minimal wear. Untreated group was demolished. These films are still evolving in motorcycle use for friction reduction but have yet to be proven as the answer to wear.

4. Complete magnetic particle testing machine by Magniflux is obviously very expensive. The cost of having parts Magnifluxed at checking stations is cheap insurance against possible major failures. Circular rig indicates electromagnetic longitudinal field to be induced into crankshaft.

form and tighter grain structure. Normally gears are made with a certain amount of built-in brittleness; Mar Tuffing removes brittleness but not strength or hardness as in many other methods. In fact a Mar Tuffed gear is 10 to 15 percent stronger and 2½ times tougher at the same previous hardness. These amazing, and proven, results occur thusly: Most gears have five to 25 percent of retained austenite, a less-strong crystalline structure acting like an impurity amidst the stronger martensite formation which dominates the gear's structure. Mar Tuffing has the unique ability to convert most all the retained austenite into martensite so the steel is now nearly a 100 percent martensitic network which is tougher and stronger but less brittle. Life on ring and pinion gears in the top fuelers of Tony Nancy, Don Prudhomme, etc:, has increased five times over other methods and Pepe is pleased beyond description. He's done several sets of bike gears which are presently in service with no problems. Cost is $20.00 per set.

HARD CHROME

Wear may be improved on most steel parts by hard chroming, which differs from the chrome on your mufflers by being plated directly to the metal without the usual preparation layer of copper and nickel plating that decorative chrome must have. The inherent hard and tough qualities of chrome are responsible for extended wear and its natural porosity aids the retention of lubricants. Usually about half a thousandth of chromium is flashed on valve stems, piston rings, rockers, timing gears, transmission cam plates, automatic advance mechanisms and sprockets at a cost of about $25.00. Shot peening always precedes the plating so these two processes combine to provide the same double benefits of Tufftriding—both fatigue and wear resistance.

Sometimes aluminum and iron cylinder bores are hard chromed, either to create a porous surface to better hold oil or as a resizing method to eliminate overboring on cylinders which face undue wear in racing. Hard chrome doesn't improve performance, just wear.

One precaution that must be taken after chroming is to temper for hydrogen embrittlement relief. Hydrogen diffused into the surface during plating promotes crystallization which embrittles metal and reduces its strength. Four hours in a 375° oven literally cooks hydrogen right out of the metal and is the only way hard or decorative chrome on a stressed part is rendered safe. Chopper guys take note.

Hard chrome is used by most of the AMA racers with great success and can improve the life of your bike when applied by firms familiar with its motorcycle applications.

HEAT TREATING

Heat treating alters the strength and hardness of metal by rearranging its molecular structure. If you find it hard to understand how controlled heating can change the properties of steel, remember that diamonds and graphite are both forms of carbon, one hard and one soft, the particular structural arrangement of the same atom determining the difference. It takes great heat to arrange carbon in its diamond form, and different heats for different exposure times to produce graphite from carbon. In the same way heat treating can vary the arrangement of grain boundaries, crystalline networks and molecular bonding in metal, all of which affect its strength and hardness. Treatment can be used to anneal (soften) steel prior to machining or bending, to harden steel for greater strength and wear qualities, to remove brittleness and to relieve stresses induced by forging, welding, plating, machining, etc. (stress relieving).

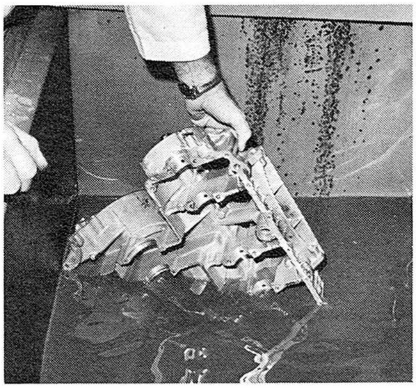
There are three steps synonymous with the single term "heat treating." First the part is heated to its transformation range, that point (usually 1500-1600°) at which its molecules are in a uniform structural arrangement called austenite. Secondly it is quenched in a liquid bath (usually oil) heated to 300-450° or 750-1000° with the temperature of the quench being related to the resultant hardness of the part—the cooler the bath the harder the metal. Quenching actually rearranges molecules into martensitic, perlitic or any other structural pattern desired. To know which pattern is best for your crankshaft, rocker arm, etc., talk to both tuners and heat treaters. The third heat-treat step is tempering, which involves reheating of the part within minutes of quenching for purposes of stress relieving and reducing possible brittleness. Improper tempering is the main cause of cracks on "new" parts. Heat treating should accompany some of the other metal treating processes such as hard chrome and nitriding.

COLD STABILIZING

Cold stabilizing is best restricted to aluminum and involves soaking a connecting rod or wheel hub in liquid nitrogen or dry ice vapors at a minimum of 100° below zero for about 24 hours. Technically this freezing "resolves grain boundaries," which means the particles making up the alloy are forced closer together. Since spaces between particles are the starting point of cracks, fatigue resistance is increased by cold stabilizing as well as strength and yield points of the aluminum. The process is tricky and should be entrusted only to professionals with direct experience in stabilizing the specific parts you are considering for treatment. Proper stabilizing followed by shot peening is the most effective strengthening treatment known for aluminum.

ANODIZING

Only aluminum can be anodized and therefore not many motorcycle parts qualify for this electrical process of controlled oxidation. But it's invaluable as a decorative finish on customs and as a barrier to corrosion on motor mounts, wheels, brackets,



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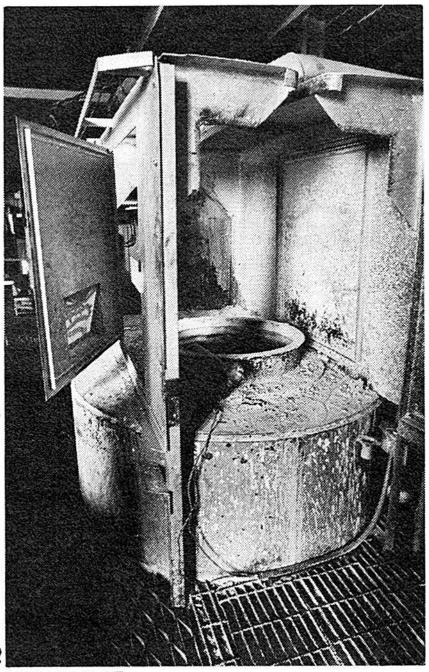
ZYGLO

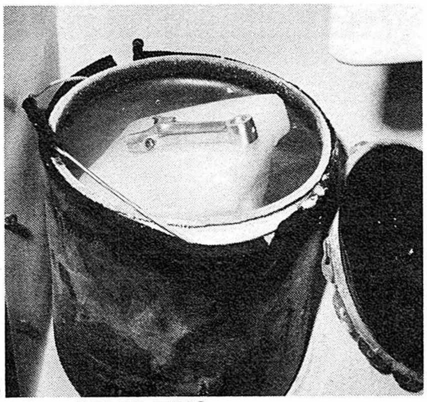
1. Zyglo testing is a method of locating cracks in non-magnetic metals like aluminum. A trade mark of Magnaflux Corp., Zyglo is a liquid process that penetrates and seeks cracks.

2. Inside salt covered furnace is where reactions in Tufftride process occur. Treatment of valve stems, cams, cranks and even fasteners is highly recommended to reduce wear, fatigue.

3. A rubber insulated bucket full of dry ice inside a refrigerator is used to drop temperatures in cold stabilization of Triumph rod. Technique works best on aluminum, takes 24 hours.



2
TUFFTRIDE



3
COLD STABILIZING

engine manifolds and cases and even on internal parts like valve keepers and collets. Anodizing has three important benefits: It absolutely prevents corrosion and therefore eliminates maintenance chores, permanent color may be impregnated into the part if desired and the anodized surface acts as an excellent primer for painting aluminum, which cannot be painted successfully without a primer.

Parts are first cleaned, then dipped in an acid bath to open pores and remove impurities, immersed in detergent, rinsed and finally hung in another acid bath from great copper bars full of D.C. current so the part acts as an annode terminal—therefore "anodizing." The electricity and acid produces accelerated oxidation (the beginning of corrosion) in the form of an aluminum oxide layer which impregnates the surface about .0002-inch. Then pop in hot water to close the pores and that's it. No more oxidation, and therefore corrosion, can occur because all that could ever occur has already been induced within a matter of 10 minutes in the tank. Like if you're pregnant, you can't get any *more* pregnant; if it's oxidized, it can't oxidize any more.

Color may be added by soaking in a bath of simple dyes prior to closing pores in the hot water dip. Black is the most common choice—thus "black annodizing." Gold, green, blue, red, etc., are also available. The new, tough surface cannot peel and is said to improve fatigue strength in some alloys. Here's a preparation hint: since anodizing only reproduces the existing surface, a part that goes in rough comes out rough. Therefore carefully smooth and polish all parts first. The effort can produce results like Ron Martin's Sportster, one of the finest customs in America. Prices are minimal for motorcyclists since costs are usually determined by the amount of tank space used. Likely you'll get away with the $5.00 minimum, but bulky cases or wheel rims may push the figure to around $25.00. If you've decided to get something anodized strictly for its effect as a primer, ask the plater's technician about Alodine or Iridite chemical films which are cheaper and designed specifically as primers.

DRY FILM LUBRICANTS

The subject is too hot for us to handle, definitely a ball of snakes. One tuner swears by Microseal, another says Everlube is the only one that works. A third maintains nothing surpasses oil as a lubricant. *Motorcyclist* is suspect of most of the miracle claims, but we agree that thin layers of molybdenum disulfide bonded to metal surfaces can eventually be perfected and proven for motorcycle use. In fact Bob Gorsuch has had excellent wear improvement on numerous parts in John Hately's Triumph with a special Everlube blend designed especially for running with oil. But we'll leave it at that for now to prevent getting bitten by one of the snakes.

ABRASIVE BLASTING

You've heard terms like glass beading, vapor honing and sand blasting, but what do they really mean? Basically all are cleaning processes which remove paint, scale, corrosion and baked-on oil or carbon in preparation for painting, plating, nondestructive metal testing or simply to rejuvenate appearance. Compressed air at pressures from 80 to 150 psi propel numerous types of abrasives with such intensity that cleaning is almost instantaneous in the area of contact and paint peels and chips away right before the operator's eyes. The job takes place inside a "dry blast cabinet," usually fitted with a blower to suck away dust and a simple gravity abrasive retrieval system. Vapor honing mixes the abrasive with water to reduce dust and produce a more satin finish.

Various grades of glass spheres, crushed walnut shells, crushed peach pits and sand are available as abrasives, and sometimes aluminum oxide is added to speed cleaning. The process does not remove parent material or effect dimensions of the part. However careful cleansing of blasted parts is necessary to insure all abrasives are absent from oil galleries, bearing surfaces, etc. We've seen engines ground to oblivion by residual glass left from blast cleaning. And don't let someone with a dry blast cabinet do your shot peening—only a firm with proper peening equipment and knowhow can obtain successful results.

CONCLUSION

Logical thought patterns on the use of these somewhat esoteric treatments should run along these lines: If you have never had or do not expect any problems from certain components which might qualify for Tufftriding, hard chrome, etc.—don't bother. For instance we have learned shot peening improves fatigue resistance of coil springs up to 1370 percent, but don't blindly run down to the local aerospace peening contractor and have your fork springs bombarded—fork spring breakage is rarely a probem. But if you've blown second gear on that red and chrome two-stroke twice this year, it would be wise to call Pepe Estrada and talk about Mar Tuffing or to consider a bit of hard chrome followed by glass peening. When used properly these processes can extend the life of both you and your engine and are therefore worth knowing just a little bit about. Common sense and professional consultation will best aid your decision making.

Familiarizing you with metal treating processes and making you aware that expert help is needed in their use is the twofold purpose of this article. Because of the space limitations it has been just a scratch on the surface, but not the dangerous kind that leads to fatigue failure.

FUEL/OIL MIXTURE RATIOS

OUNCES OF OIL REQUIRED FOR VARIOUS FUEL MIXES

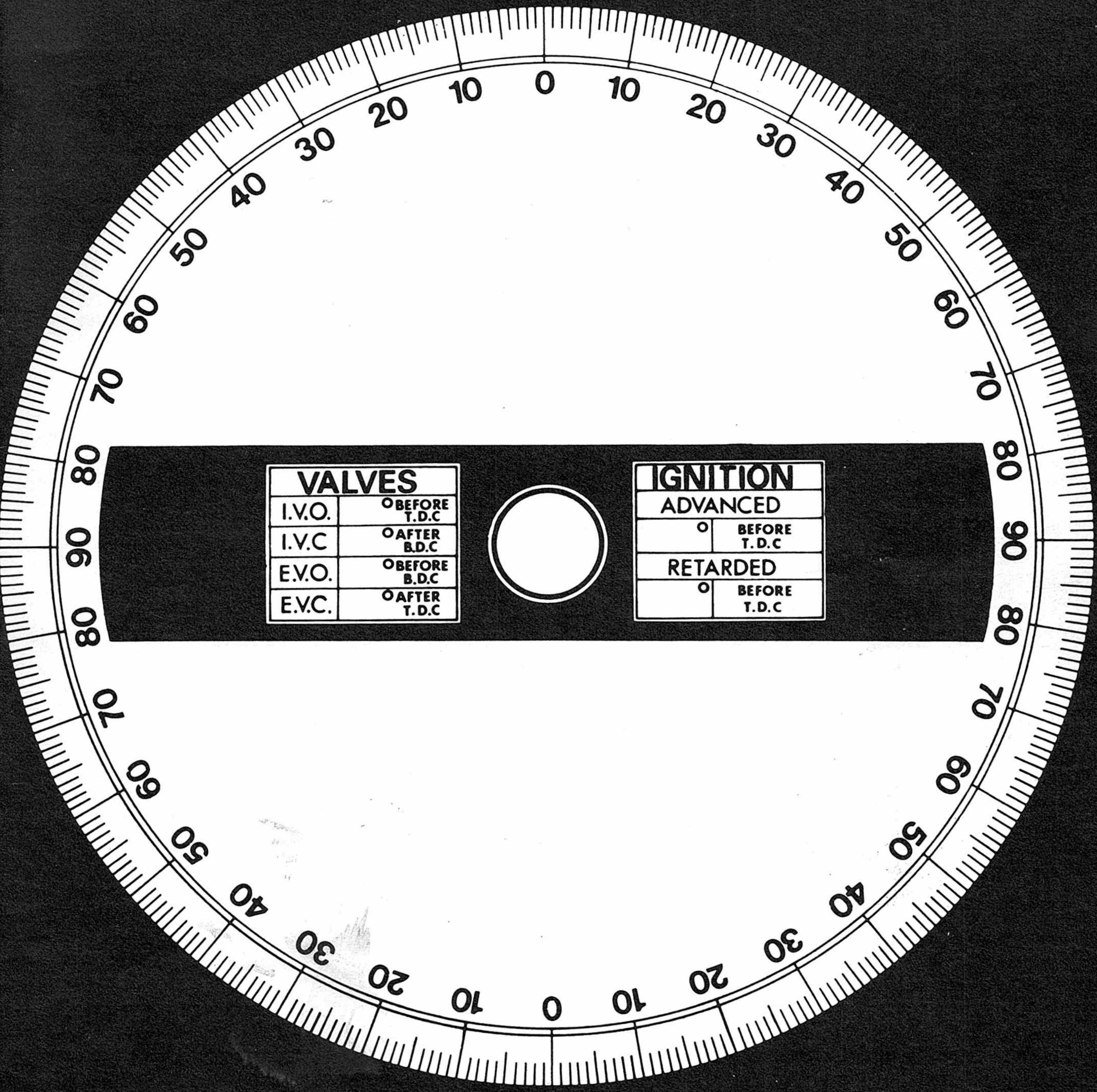
	FUEL: OIL RATIO	8:1	12:1	16:1	20:1	24:1	28:1	32:1	36:1	40:1
GALLONS OF FUEL	.5	8	5	4	3	2½	2	2	2	1½
	.6	10	6½	5	4	3	2½	2½	2	2
	.7	11	7½	5½	4½	3½	3	3	2½	2
	.8	13	8½	6½	5	4½	3½	3	3	2½
	.9	14	9½	7	6	5	4	3½	3	3
	1.0	16	11	8	6½	5½	4½	4	3½	3
	1.5	24	16	12	10	8	7	6	5½	5
	2.0	32	21	16	13	11	9	8	7	6½
	2.5	40	27	20	16	13	11	10	9	8
	3.0	48	32	24	19	16	14	12	11	10
	4.0	64	43	32	26	21	18	16	14	13
	5.0	80	53	40	32	27	23	20	18	16

Here's a handy chart to hang on the garage wall or carry in your tool box. Remember, when in a situation where you don't have a chart or the usual measuring devices, don't sweat it! A little bit of oil will go a long way. A gallon is 128 ounces, and a small Coke bottle of oil in it is pretty close to 20:1.

A very convenient and inexpensive measuring container for the shop is the ordinary baby nursing bottle, usually found in drugstores and supermarkets. They normally have a capacity of 8 ounces, graduated in ¼ ounces, along with 10cc graduations up to 240cc. Other common containers are:

6 ounces (177cc)—small Coke bottle
12 ounces (355cc)—beverage can
16 ounces (473cc)—1 pint—½ quart beverage can
32 ounces (946cc)—1 quart

SEE THE 'SHOP MATH' CHAPTER FOR COMPLETE FLUID MEASURE CONVERSION DATA.


VALVES
I.V.O.
BEFORE T.D.C
I.V.C
AFTER B.D.C
E.V.O.
BEFORE B.D.C
E.V.C.
AFTER T.D.C
IGNITION
ADVANCED
BEFORE T.D.C
RETARDED
BEFORE T.D.C

MORE HORSEPOWER

We'll tell you where it comes from, but you'll have to decide whether it's worth the price

BY BILL OCHELTREE

Obtaining something for nothing, having the most for the least, or pulling more out of a given situation than someone else is an age-old game. So it goes with machinery—especially machinery that moves people. Going faster or covering the distance in less time is the name of the game, and when it comes to the showdown, horsepower is the high card. The dealer in the game to be discussed here is the motorcycle engine manufacturer. Like all good dealers, he wants to make as much out of the game as he can. Consequently, he likes to see everybody end up with a good hand so they won't get discouraged and stop playing the game.

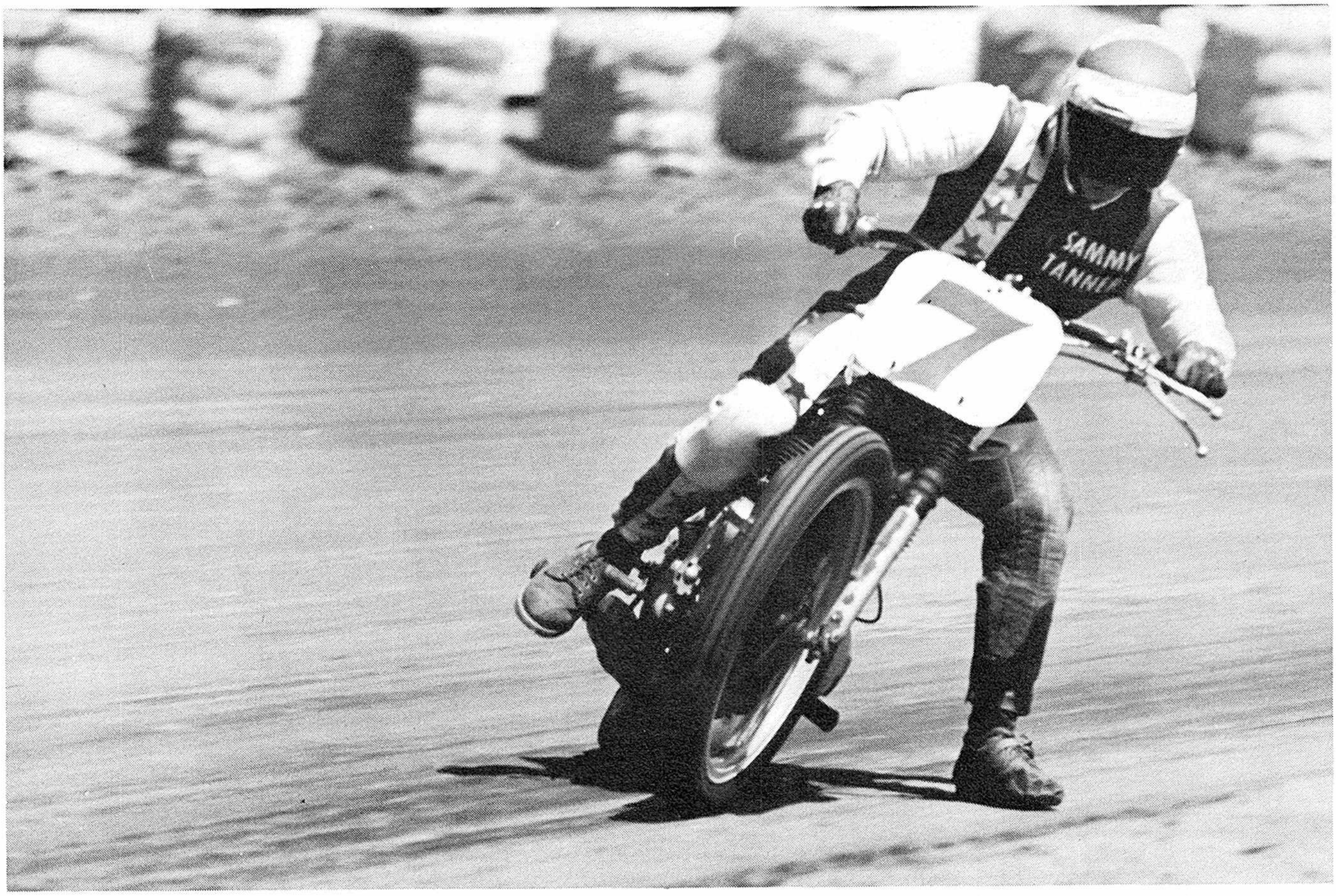
Although all manufacturers are not equally successful, the way they play the game is pretty simple. They pull the most out of what's in the pot by keeping manufacturing costs to a minimum, and they try to keep their customers happy by providing them with the maximum horsepower possible without discouraging them by poor reliability or short service life. Most modern engines are initially designed to deliver the most power possible within given displacement limits and cost guidelines. This is where potential engine performance suffers. It's just a matter of getting the most for the least, and if the buyer wants more he's just going to pay more.

The first thing to consider when going for more power is the use to which that power is put. One Friday night at Ascot is equivalent to about 2500 miles of fast highway touring! One hundred trips down the drag strip can be easier on an engine than riding to and from work, but it's like cutting for aces at $100 per cut. The Isle of Man and the Baja 500 have a lot in common for the engine to cope with, just as the same thing that can do in an engine on a trials bike can do it at an International Grand Prix Moto-Cross.

When it comes to developing more from motorcycle engine, it usually can be had, but not without sacrifice. Many exotic space-age materials and manufacturing techniques could be used to provide a strong engine capable of tremendous output, but the cost would be staggering. On the other hand, if expectations are kept within the actual capabilities of the engine, a respectable gain in horsepower may be achieved with very little loss in reliability and life.

TEMPERATURE AND LOAD

Two basic factors which are inherent in engine operation are also the culprits which cause ultimate failure: Temperature and load. The heat of burning the fuel in the combustion chamber is the source. Of all the heat generated by this burning, only about 30 percent of it is converted to pressure to force the piston against the load, and about 15 percent of that is



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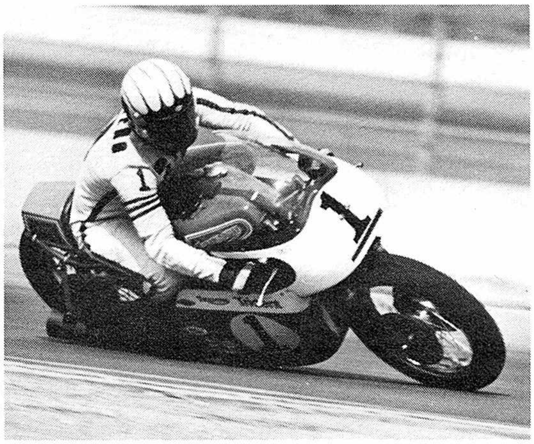

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1. One run across the Bonneville Salt Flats is like a hundred miles on a street engine. Heat and friction must be precisely controlled in the shell.

2. In less than ten seconds, these engines will burn half a gallon of fuel in just 1320 feet, albeit effectively use only 30-percent of it to convert pressure to force the piston against load.

3. In high speed engines the inertial loads of reciprocating parts can be far greater than the working loads.

used up within the engine doing things like sucking in air, pushing out exhaust, opening and closing valves and all the housekeeping chores of just running. Most of the 70 percent of the heat that is lost goes out in the exhaust gases, but a good amount goes into raising the temperature of all the engine parts.

All materials exhibit a property called "creep" or "cold flow." This is a plastic deformation which occurs under load over a long period of time. At elevated temperatures the rate of deformation increases rapidly under a given load, even when the loads are relatively low in comparison to the usual short-time strength of the material. High temperatures also reduce the basic strength of a material especially in low melting point materials like aluminum, lead and other bearing materials. It is the reduction in strength at elevated temperatures of these basic materials that is the greatest single factor controlling the rate of wear in an engine. Abnormally high temperatures can of course bring about failure more rapidly than long-term wear suffered at normal operating temperatures. General overheat conditions usually result in piston or bearing seizure, while local hot spots are the cause of melted pistons, mushroomed valves or blown head gaskets. Conditions of this nature are generally the result of a situation where the engine is performing at an unusually low thermal efficiency. This is where the energy of combustion goes into the heating of the engine rather than into mechanical work. The causes for this are varied but can usually be traced to careless maintenance or over-zealous and uninformed attempts at obtaining more power.

Mechanical loads imposed on engine components are generally classed either as external, as a result of the work applied through the drive train in propelling the bike, or internal from the necessary mechanical operating functions or inertial forces generated by reciprocating parts. The nature of the forces involved have noticeably different effects on the materials and the actual usable strengths of the materials are affected by the manner in which the forces are applied. There are three types of loading to which materials react in different ways: Continuous or static, impact or shock, and periodic or cyclic. A steady or slowly changing force applied to a material until it breaks is the loading upon which the ultimate strength of the material is based. A load somewhat less than ultimate but applied and released in a cyclic fashion over and over can still result in the failure of material after some definite number of cycles. This phenomenon is called fatigue. The highest periodic load which may be applied without failure, regardless of the number of cycles, is called the endurance limit. For iron and steel alloys endurance limits are about ⅓ to ½ the static strength and in materials like aluminum and copper alloys the endurance limit can be as low as ⅓ to ¼ ultimate. The speed at which a force is applied to a material will also cause it to show different strength characteristics. A very rapidly applied shock load in excess of the ultimate strength may not cause failure under certain ideal conditions, whereas a shock amounting to a small fraction of the maximum static load will cause failure under more adverse conditions. The actual conditions under which impact failure occurs are so varied that it is difficult to place specific values on the impact resistance of various materials. Therefore,

attempts are made to avoid or minimize shock loading by absorbing the loads over as long a time period as possible.

The most critical external engine loads are those transmitted through the drive train to the crankshaft. Rapid clutch engagements, gear shifts or the sudden discovery of traction by a spinning wheel can put tremendous loads on the crank, rod and piston, and these of course must be accounted for from both the standpoint of ultimate load and fatigue. Internal engine loads are generally all of a cyclic nature directly proportional to crankshaft rpm. These loads are grouped in two categories for the purpose of analysis. One set of loads are those arising from the performance of work, both internal and external; the others are those generated by inertial forces due to rapid acceleration and reversal of reciprocating parts.

Working loads are felt by all engine parts during normal operation. External work is reacted by the crank, rod, piston, head, cylinder and crankcase; and internal work is performed throughout the valve train, lubrication, ignition and electrical generating systems. Work is also performed in drawing in the air/fuel mixture and in pumping out of exhaust gases. Internal working loads are generally constant or near constant while external loads and pumping loads are controlled by carburetor throttle opening.

In very low-speed engines, the working loads are most important, while in high speed engines the inertial loads of reciprocating parts can be far greater than the working loads. Inertial forces are dependent solely on the weight of the reciprocating parts, the distance which they travel back and forth in and on the square of the engine speed. A high-compression piston weighing 5½ ounces versus five ounces stock, or increasing a 2½-inch stroke by ¼-inch will increase rod and crank loads by only 10 percent, but taking an engine red-lined at 7000 rpm by the manufacturer, up to 10,000 rpm doubles the inertial load on all the reciprocating parts and their supporting structure.

The external loads to which an engine is designed are based on the maximum expected horsepower, the maximum weight of bike and rider which the engine is expected to pull, and the maximum speed expected. These loads are then multiplied by the maximum expected accelerations in various directions based on experience. The internal loads are based on the weights of the parts, some maximum rpm limit, acceleration rates, combustion pressure, and maximum temperatures. Once these working loads are established then each part is examined for fatigue factors depending on the type of material and expected service life. Then the working loads are multiplied by an appropriate factor of safety to establish the actual design loads. These factors of safety may range from 1.5 to four depending on the uncertainties involved. Forged parts are generally designed with factors of 1.5 or two, where similar castings are given a factor of three or four. In cases where a fatigue factor has been applied this may also serve as a safety factor.

Most major engine parts, crank, rod, piston, crankcase, cylinder, head and valve train, are designed with safety factors of four or more to account for both fatigue and inertial forces. As stated above, inertial loads are the most critical in high speed engines and they are proportional to rpm^2. Doubling the manufacturer's recommended maximum speed applies four times the forces for which the engine was designed and anything in excess of these loads will probably cause failure. Many super-tuned dragsters approach these limit loads, and this is where a missed shift or too fast a throttle shut-off can mean destruction. In the hands of a capable pilot, an engine may be operated at limit load for a considerable length of time, but when the safety factor goes away so does endurance. This is why very high-speed engines require complete teardown after as little as 10 hours of operation. Under such conditions, parts such as bearings and pistons, and the entire valve train: Cam, followers, pushrods, rockers, valves, and springs, show wear normally seen in an engine after 50,000 miles!

Although there isn't much to wear out in some parts, they are still subject to fatigue caused by repeated loading and unloading. The first evidence of fatigue is the appearance of microscopic cracks on the surface of a part or in areas of stress concentration such as sharp corners, notches or abrupt changes in cross section. The progress of these cracks in their early stages is very slow, but once a crack reaches the stage of being barely visible to the eye it can soon result in failure. Inspection methods such as "Magnaflux" or "Zyglo" can assist in finding cracks in their earliest stages

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of visibility. Connecting rods and cranks are commonly inspected this way and it has proved to be very good insurance. Fatigue failure due to adverse surface conditions may be minimized by removal of all scratches, roughness and irregularities, and by reworking to eliminate sharp corners and edges and providing gradual transitions between various features. The surface may then be treated by a method called "shot peening," where the part is gently blasted with, or tumbled in smooth steel pellets to provide a microscopic hammered effect which is a deterrant to fatigue cracking.

ENGINE SPEED LOADS LIMITS

Unless the object is all-out speed on an unlimited budget, excessively high engine speeds are not necessary for most applications. Moderate increases over red-line rpm can be helpful without harmful effects. An increase of 12 percent in rpm will result in inertial load increases of 25 percent. This is well within limit loads and in most cases will not exceed endurance limits. A push of 23 percent over red-line boosts loading by 50 percent which effectively reduces safety factors by half. This could lead to trouble, but with careful operation, impressive performance may be demonstrated. Most endurance limits will be exceeded at this loading however, and special preparations such as shot-peening, dynamic balancing and appropriate material substitutions should be made. Periodic inspections should also be made, but these may be extended as confidence is developed.

Let's delve into some math for a few minutes, and show how horsepower is produced.

$$H.P. = \frac{P \times L \times A \times N}{33,000}$$

In the above equation, the figures represent the following:

H. P. = Horse Power

P = mean effective Pressure (mep) in pounds per square inch (psi)

L = Length of stroke in feet (stroke in inches ÷ 12)

A = Area of bore in square inches (.785 x $bore^2$)

N = Number of working strokes per minute (wspm) (RPM x No. cylinders [* ÷ 2])

*If a four-stroke

A brief analysis of this fundamental equation is as follows:

Pressure in psi multiplied by the area in square inches against which it is exerted equals the force in pounds (F) on the piston. Combining P x A we have

$$H.P. = \frac{F \times L \times N}{33,000}$$

The force in pounds on an object multiplied by the distance in feet it moves because of the force equals the work in foot-pounds (W) which is applied to it (don't confuse foot-pounds of work with foot-pounds of torque, see below). Combining F x L yields:

$$H.P. = \frac{W \times N}{33,000}$$

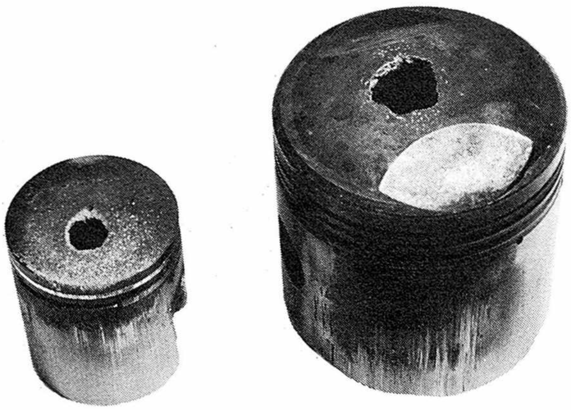
Now, when something is moved through a distance, time is involved so that if the number of times that this working stroke occurs in one minute is multiplied by the work value in

1. Most major engine parts are designed with a safety factor of four or more. Generally, the larger the engine and its parts the more care must be used prior to stretching its work loads.

2. Most of the 70-percent of the heat produced is lost going out the exhaust; but too much heat going back into raising engine temperatures can cause this.

3. Doubling the manufacturer's recommended speed applies four times the force for which engine was designed. Such excess loads spell disaster.

4. Exceeding the red line by 23-percent will boost loading by 50-percent. This some bearing parts cannot hold.



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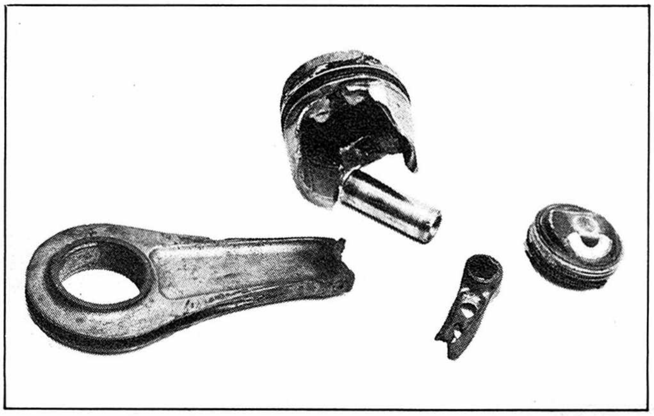

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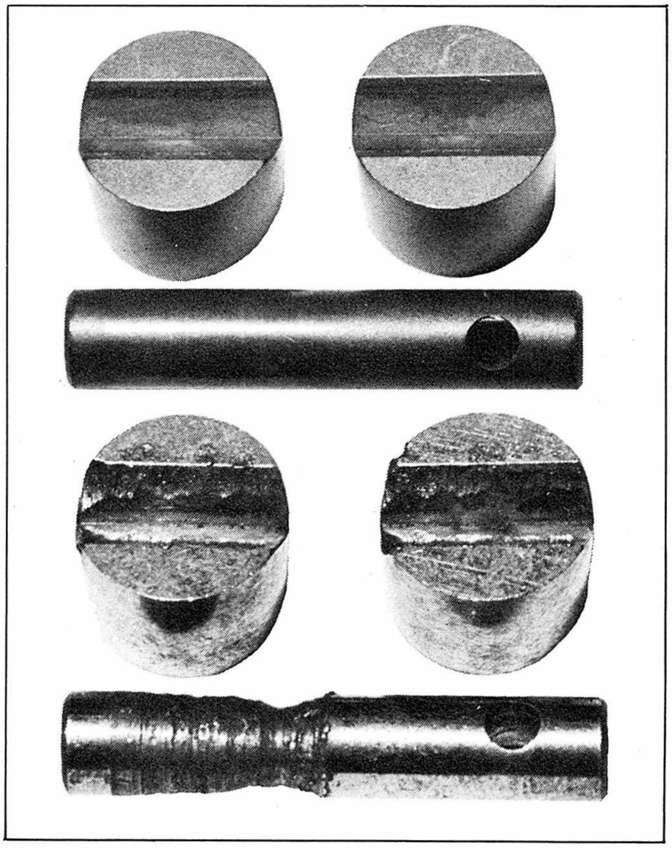

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foot-pounds, we arrived at a value of the rate at which this work is applied in foot-pounds per minute.

Foot-pounds of work is a measure of energy. It implies motion of an object which requires exertion of a force over the entire distance and in the direction of movement.

Foot-pounds of torque is a measure of force. There is no motion implied; instead, torque is an indication only of the direction of a force. Torque is the force applied to an object which is fixed at some point but which may rotate about the point at which it is fixed.

Torque (T) is measured by the distance in feet (R) from the point of rotation to the point at which the force is applied, multiplied by the force in pounds (F) applied at a right angle, or normal, to a line drawn through the point of rotation and the point of force application (T = R x F).

If movement occurs due to torque, then work is expended. The movement is, of course, circular, and if the force applied is constant and always directed along the circumference of its circle of movement then the work (W) is equal to:

$$2 \times \pi \times R \times F \times n$$

2 x π x R is the circumference of the force circle and n is the number of revolutions thus giving the total distance through which the force is applied. Another way of expressing this is:

$$W = 6.28 \times T \times n.$$

If rotation is continuous at a rate of N (RPM), then:

$$H.\ P. = \frac{6.28 \times T \times N}{33{,}000} = \frac{T \times N}{5{,}250}$$

Power is the rate at which work is performed and one horsepower is defined as work performed at the rate of 33,000 foot-pounds per minute, so:

$$H.\ P. = \frac{\text{foot-pounds per minute}}{33{,}000}$$

Here, then, are the three factors, or parameters, that govern engine output:

1. P, the pressure exerted on the piston by the gasses generated in burning of the fuel.
2. L x A, the displacement (when L is in inches) of the volume of gas in the cylinder due to piston movement.
3. N, the rate at which the combustion process is occurring and forcing piston movement which is a direct function of RPM.

Let's look at these a little closer now to see how they affect engine performance and each other.

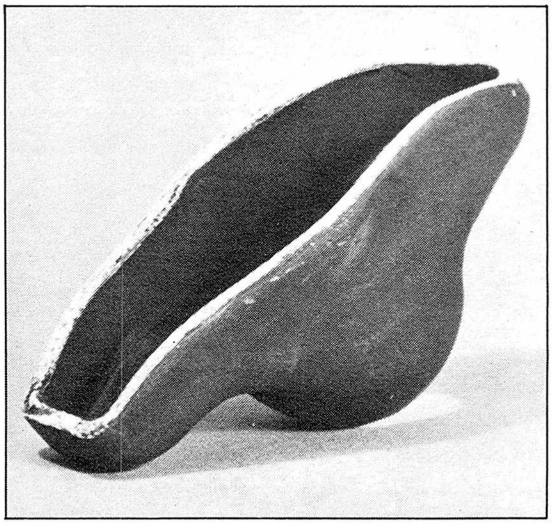
THERMAL EFFICIENCY

A little over 200 years ago an Englishman, James Watt, invented the steam engine. It was such a marvel that it sent the scholars of the day into ecstacy in analyzing its physical and mathematical characteristics. Within 50 years after the invention of the steam engine, all the theories, laws and mathematical relations governing the behavior of gases under the effects of heat and pressure were formulated by various men who had never heard the word "thermodynamics." One of the novel ideas that came out of all this study and theorizing was the air engine. Once it was realized that the conversion of heat energy into mechanical energy required the action of some fluid medium to convert temperature changes into pressure, someone said, "Why boil all that water when air is so plentiful?" The idea, of course, was that an engine should draw in a volume of air, compress it, and then somehow heat would be rapidly applied to raise the pressure and obtain useful work. Well, it was 25 years before oil was discovered in Pennsylvania and another 25 years until someone found that gasoline might make a good fuel for the air engine.

The basic process that takes place within the engine to produce power is really very simple. It is based on the fundamental gas law that says the pressure within a given amount of any gas is directly proportional to the temperature and inversely proportional to the volume.

Consider an engine where the intake valve closes at bottom dead center, and it has a compression ratio of 9.0:1. If the air/fuel mixture could be compressed without any loss of heat so that there would be a normal rise in temperature, thus adding to the pressure, then the compression pressure would reach 260 psi and the temperature, if it was 60°F to begin with, will rise to 819°F. Now suppose we light the gas. At this point the piston is at top dead center. Theoretically, the fuel is burning in a constant volume so the basic gas law that says pressure is proportional to temperature would apply. If the amount of fuel burned can raise the temperature of the charge by about 3800°F (which it can easily do) the temperature in the combustion chamber will become 4619°F and the pressure will go to 1077 psi.

The work that this pressure can do minus the work it took to compress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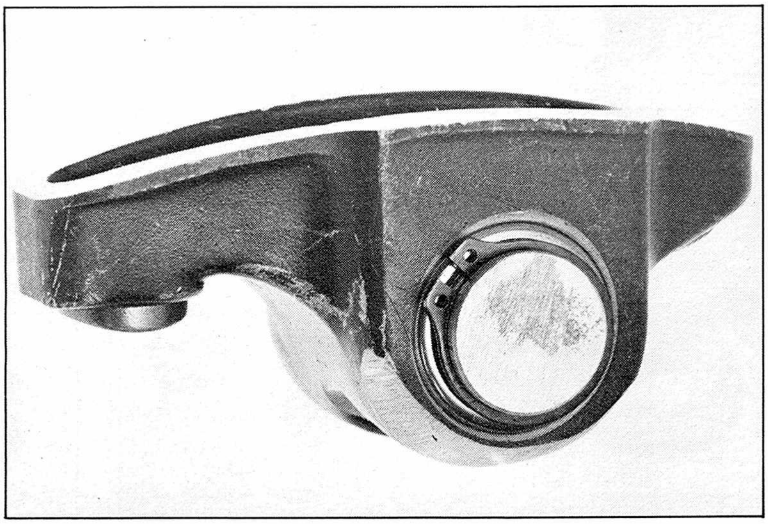
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the charge originally represents the thermal efficiency of the engine. If this same engine has a compression ratio of 10:1, the compression pressure will be 298 psi at a temperature of 855°F. The same amount of fuel burned will raise the temperature of the charge by the same amount, but the combustion pressure will rise by a greater amount than previously to 1202 psi. This indicates an increase in thermal efficiency, and it can be shown that the thermal efficiency of the ideal engine cycle is directly related to the compression ratio.

The diagram in Figure 1 illustrates the difference between the maximum pressures used in the analysis of the ideal cycle and the mean or average pressure available over the entire piston stroke. The compression pressure represents negative work, so when subtracted from the positive combustion pressure it gives an indicated mean effective pressure (imep). The work available due to imep is further reduced by the necessary pumping and mechanical work, so that the work actually available at the crankshaft for measurement on the dynamometer is measured in brake mean effective pressure (bmep). The piston actually sees the peak pressures and all parts must be designed to withstand them, but what is actually usable is averaged out over one complete power cycle of the crankshaft.

1. The air engine requires a great deal of the power it produces to move, spin and lift its own parts. Heavy, stamped steel rockers rob a potentially powerful engine of precious energy by having too many ounces weight.

2. Giving a lifter a parallel round surface to ride on lowers its frictional drag and raises the efficiency.

3. Reducing weight by using alloy castings and forgings reduced the cyclic weight working load demand.

4. Mechanical efficiency diminishes with speed and friction. A roller bearing rocker is 98-percent efficient.

A first look at this simplified engine process analysis might raise the question: Why not deliver more fuel into the cylinder? In both theory and practice what is being discussed here is an air engine. The burning of gasoline, or any other fuel, is a chemical process that requires oxygen for the liberation of heat. Every pound of gasoline burned requires the oxygen found in 15 pounds of air. Now an engine can only take in so much air at a time, so any fuel in excess of that which uses all the air is wasted. The next question regarding the engine process is: Why not just raise the compression ratio?

IGNITION TEMPERATURE & FLAME SPEED

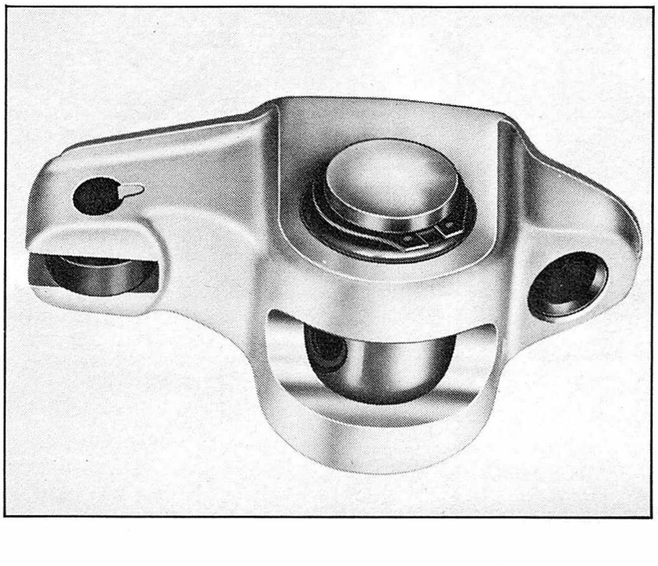
In addition to the thermal and structural loads imposed on the machinery, temperature and pressure have marked effects on the combustion process itself. The two factors in combustion which are most affected by compression ratio are ignition temperature and flame speed. The primary effect is on ignition temperature where the higher the pressure, the lower the ignition temperature. When the fuel/air mixture is at ignition temperature, there is a time lag before spontaneous combustion occurs, and if the flame from the spark ignited combustion can reach all parts of the chamber before this happens there will be smooth burning. Fortunately, the secondary effect of high compression is to increase the flame speed. Flame speed is also increased by turbulence in the air/fuel charge. Turbulence is primarily dependent on the way in which the charge enters the combustion chamber and in the shape of the combustion chamber. Piston speed also has an effect on turbulence with higher flame speeds generally resulting at higher engine speeds.

Higher compression ratios do have the assistance of other effects up to a point, but the major difficulty still lies in the ignition temperature of the fuel. As stated, there is a time lag for auto ignition to take place, but as the mixture temperature goes up over the ignition temperature the time lag becomes shorter. When conditions are such that the temperature and pressure in front of the combustion flame cause auto ignition of the remaining unburned charge, there is an instantaneous inflammation of the entire portion which results in an extremely high local pressure rise which can be heard as the old-fashioned "knock."

An occasional metallic tingle at wide open throttle is generally nothing to cause alarm, but when it sounds like someone is beating the head with a hammer, something is wrong. An extensively modified engine should be able to operate at standard spark timing, and retarding of the spark to compensate for increased compression will defeat its purpose by lowering thermal efficiency and causing higher engine operating temperatures.

VOLUMETRIC EFFICIENCY

The main problem in extracting power from an engine is all the power that it takes just to keep the engine running. Well it is an air engine and the more air it draws in, the more fuel it can burn to produce more power. Of course, it's pretty difficult to make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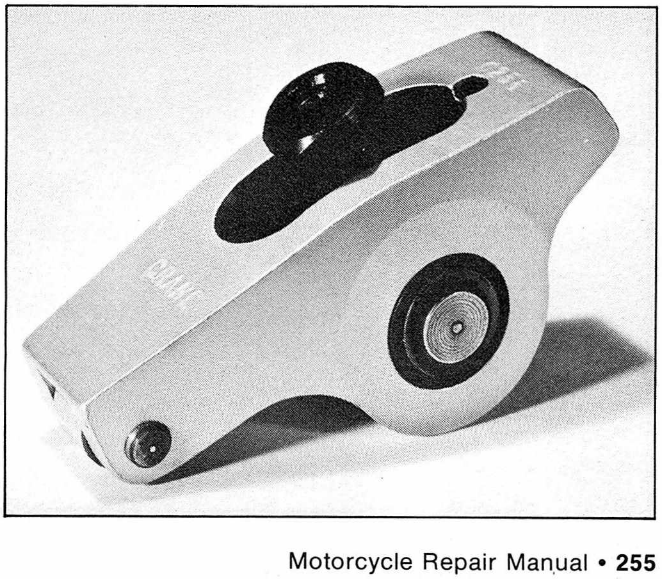
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a 40 cubic-inch engine inhale more than 40 cubic inches of air at one time without a supercharger, but to show that there's room for improvement, consider that a 40-inch engine does well to inhale more than 30 cubic inches at a time and that about half the time it's only drawing in about 25.

The free air of the atmosphere is subject to the same gas laws as confined gases, but it behaves a little differently because it is not confined. A cubic foot of air, at 68°F and absolute pressure of 14.7 psi, weighs .075 pounds. It is said to have a density of .075 pounds per cubic foot. Now, if this air, and all the air around it within some distance is heated so that its temperature rises, it will expand in direct proportion to the rise in temperature, and having expanded, a cubic foot will now weigh less than .075 lbs. Similarly, if the pressure is reduced, the air will expand resulting in a lower density.

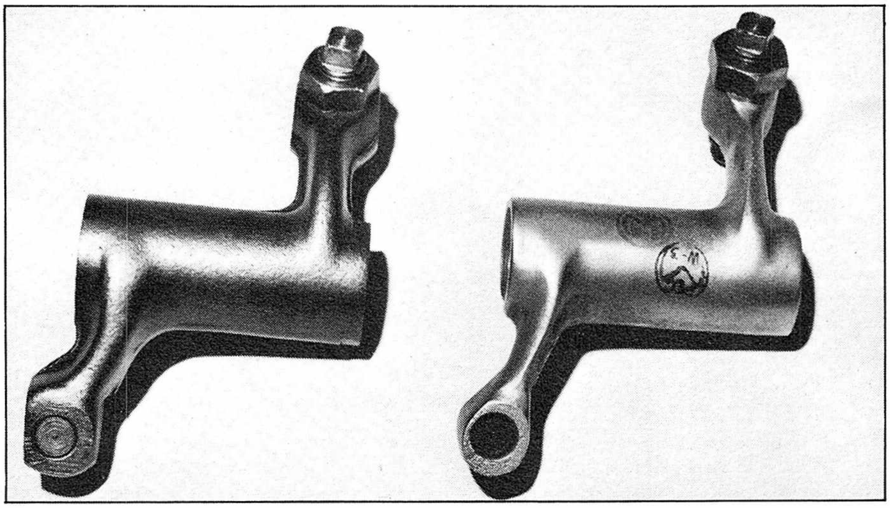
When an engine is running, considerable vacuum is created in the intake port because of restrictions, the greatest restriction being the port itself. Even without a valve in it, the cross sectional area of a port is about 1/6 the area of the cylinder bore. If the piston is moving away at a speed of 3000 feet per minute, the incoming air must follow at the same speed, but when the area that it must pass through is only 1/6 of the piston area then it has to go six times as fast. The air starts from zero speed outside the carburetor, accelerates to 18,000 fpm through the whole intake passage and then slows down to 3,000 fpm as it enters the cylinder. It tries, but can't keep the pace, so it just thins out and does the best it can. In doing so, its density is reduced which is evidenced by a drop in pressure. The incoming air also picks up considerable heat from the port, valve, head, cylinder and residual exhaust gas so that a temperature of 180° with a pressure three psi below atmospheric is not unusual for an air/fuel charge before compression begins. Well, air under these conditions only weighs .050 pounds per cubic foot, which would indicate that there is only about 67 percent of the air that ought to be in the cylinder. This 67 percent is called the volumetric efficiency.

Volumetric efficiency can range anywhere from 50 percent to 90 percent, depending on engine speed, temperature, intake restrictions and valve timing. Volumetric efficiency is the most *significant factor* in the generation of effective pressure for the production of power. As stated above, a supercharger can push the full displacement into a cylinder and even more if the engine can take it; but for virtually all forms of competition and most all other phases of motorcycling the only way to obtain more power out of a given engine is to reduce the restrictions on the intake as much as possible and then take advantage of the energy of the incoming air to have maximum charging. Although it takes quite a bit of energy to accelerate intake air up to 18,000 fpm, once it attains that speed it tends to keep moving even after the piston has reached bottom center and started to move up. This is why that in practice the valve timing is such that the intake closes later than bottom center. If the valve timing is late ("radical") and the engine is running slowly, this can be a disadvantage as some of the charge may actually be pumped *back out* before the valve closes. This is where care must be taken in selection of cam timing. This is the primary reason why many all-out engines tend to run very poorly at low speeds and have a "lumpy" erratic idle.

For a given set of conditions of displacement and rpm range, mean effective pressure is the force that makes the bike go. It starts with the taking in of the air/fuel charge, the size of which is dependent on the volumetric efficiency; the charge is then compressed and ignited to generate a pressure which is dependent on the thermal efficiency. The thermal efficiency is directly proportional to the compression ratio which is limited by the burning characteristics of the fuel. This pressure then diminishes very rapidly while forcing the piston to turn the crankshaft and flywheels to obtain usable energy. Some of this usable energy is immediately returned to pressure to compress the next charge and the result is imep. Some more energy is then given up to mechanical and pumping losses and the rest is finally available as bmep which can be measured as torque.

NO REPLACEMENT FOR DISPLACEMENT?

Obviously, of two similar engines with different displacements but of the same mep at the same speeds, the one with greater displacement will have more power in direct proportion with the displacement. This would appear to be the simplest way to obtain more power out of a given engine design, and it is, for a manufacturer when he wants to boost falling sales. It's also an easy way out for the guy who wants brute force at low speed and doesn't want to be bothered with



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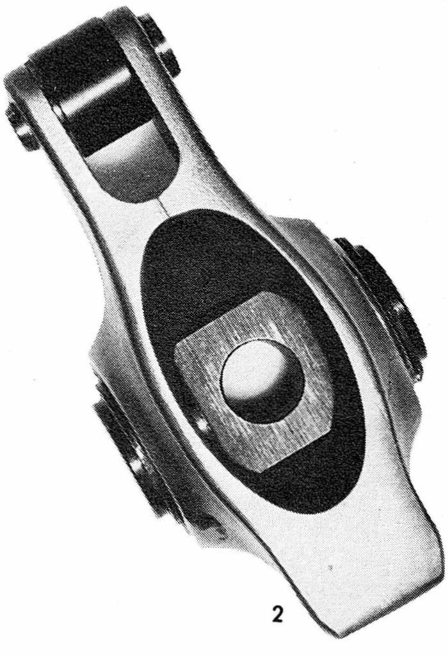

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all the details that go with the more sophisticated tuning techniques. Competition classifications often prohibit increased displacement without penalty of moving to the next higher classification, but on the other hand a perfectly good engine which is a little undersize can easily be opened up to the limit of the class in which it is otherwise handicapped. A 650cc Triumph needs only an additional 3/16 inch on the bore to bring it up to the 750cc limit for A.M.A. professional competition and that's an automatic 14 percent jump in horsepower, all other things being equal. A similar job on a 500cc Triumph will yield a 15 percent increase, but at 575cc it's way out of its class.

Displacement increases to an existing engine should be very carefully considered from the standpoint of the type of use, reliability, and cost. The first thing the engine sees after being enlarged is heavier reciprocating parts which means that rebalancing the crankshaft is required to keep it from shaking itself apart. Increases in bore size only, results in a larger piston which can usually approximate the weight of the original piston by removal of excess material in the skirt area. Moderate bore increases can be accommodated by most stock cylinders, but for large over-bores, a thick-wall replacement is required which usually requires crankcase rework. Stroking is a job requiring extensive rework of crank, rod and piston and is generally most economically feasible on small displacement engines.

In terms of dimensional changes only, displacement is proportional to the stroke and to the square of the bore. That is, ¼ inch increase on a three-inch stroke is a displacement increase of eight percent, but ¼ inch added to the cylinder diameter is a 17 percent increase. The same type of relationship holds true for multi-cylinder engines versus singles.

The letter N, the rate at which fuel is burned and heat supplied to the engine has special significance in the reciprocating engine. Unlike many power sources which are continuous in operation such as turbines, the reciprocating engine is cyclic in operation and the working parts must play multiple roles. The piston acts as suction pump, compressor, pressure transfer element and scavenging pump. Each of these functions is alloted a discrete time segment within the cycle and as the cycle repetition rate is increased, the time for each function is decreased accordingly. The actual rates at which these operations occur is constant so that if the time alloted to them is reduced then the space requirements must be reduced in order to allow them to be carried to completion. This philosophy has been successfully utilized in the legendary Honda racing engines, but the complexity of these multi-small-displacement-per-cylinder engines is costly enough to make even Honda take an occasional breather for refinancing! About all that can be said about more revs from a given engine is that you take what you comfortably can without blowing it.

Mechanical efficiency does diminish with speed due to increased friction. Most of the friction in engine operation is in the sliding of the piston and there just isn't much that can be done about it. Some processes of impregnating pistons with lubricating agents have shown measurable increase in mechanical efficiency, but the coatings require frequent renewal to maintain effectivity. Comparative mechanical efficiencies for various machine elements are:

plain bearings	97 percent
roller bearings	98 percent
ball bearings	99 percent
spur gears	96 percent
roller chain	98 percent

It must be born in mind that bearings are selected not only for cost but for load carrying capabilities and lubrication requirements. If all bearings in an engine were plain bearings it may be worth while to convert to roller or ball, but to change one or two seems hardly worth the effort unless there are peculiar problems involved.

This is all theory deduced from now proven efficiency, or lack of it, of the gasoline/air engine. Once consumed and digested, it is now time to consider the value, cost and desired results of increasing the efficiency therefore the horsepower and torque output of a motorcycle engine. All of this "theory" is based on constant and/or ideal conditions and make the task of physically and mechanically applying this knowledge in an uncontrolled environment an optimum challenge. It all boils down to the fact that speed costs money, how fast can you afford to go?

1. **Precious hours went into lightening, then shot-peening, the rocker arm on the left to look like one at right. Weight was reduced, strength increased.**

2. **Most critical to maximum performance is volumetric efficiency, which can be improved by better breathing. High-speed engines demand minimal friction in the valve train system.**

3. **Compression pressure represents negative work to produce positive pressure.**

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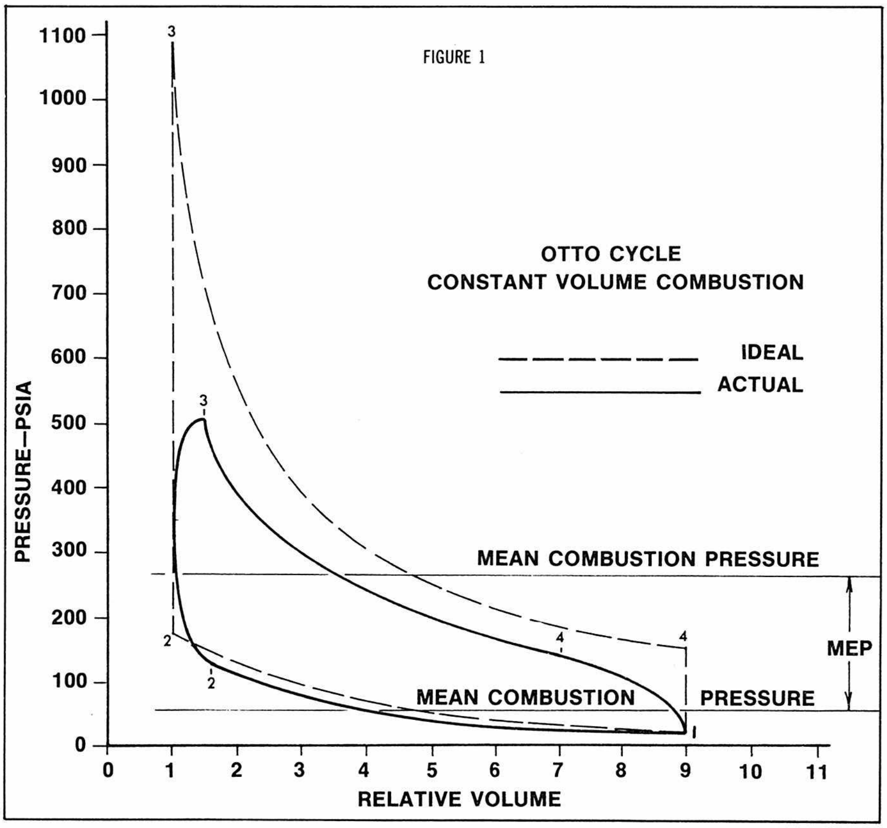


TWO-STROKE HOP-UP

It's a nice place to visit. But are you sure you'd like to live there?

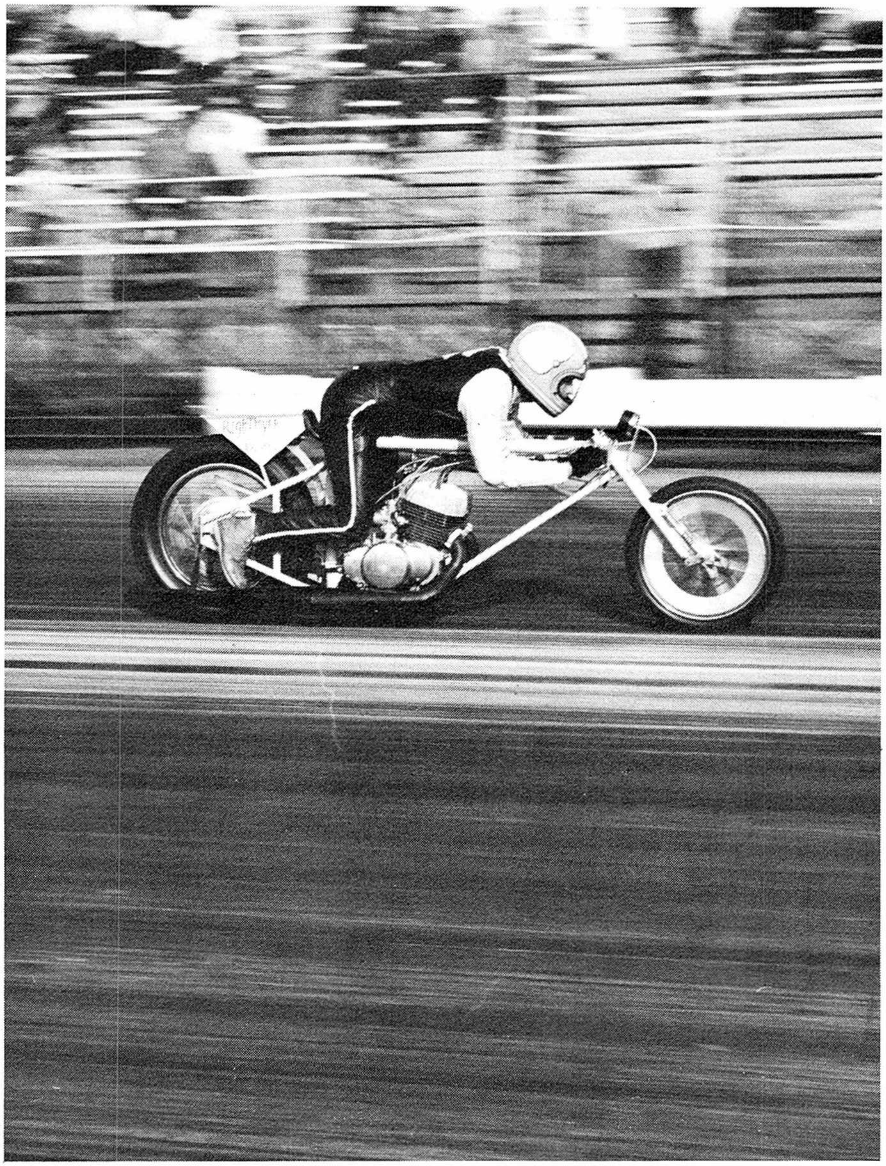
BY TONY MURPHY

Sooner or later everyone has the urge for more horsepower. Once you run across a few hills you can't climb, or a few friends that you can't keep up with, you start thinking about squeezing some more ponies out of old faithful. Maybe an expansion chamber and bigger carburetor will do the trick. Maybe a trick reed valve setup or milling some meat off the head will be the answer. All that stuff's pretty easy to do, and although it doesn't appear for free it is a lot cheaper than splitting the crankcases and stuffing the lower end. But which ones will do the best job? Just how can Joe Average go about improving the engine performance without spending so much time and money that he'd have been better off buying a newer, more powerful machine in the first place?

If you're not one that likes to spend hours in the garage fiddling with the engine, you're a sure candidate for a new machine. If you do enjoy twisting wrenches you may experience the frustration of bolting on all the tricks and find out that you have only *changed* your machine, not improved it. Before you lift a wrench out of your tool box or a bill out of your wallet, ask yourself one simple question: "What do I want my machine to do that it doesn't do now?" Ponder it for awhile, consider all the pros and cons of what you have, then set out to improve the weak areas without harming the strong ones.

What is the machine used for? What was it intended to be used for? How does your particular model compare with other examples of the same model? Maybe yours is just not up to par and with a tune-up or gearing change would show a marked improvement in performance. Maybe there is no way to make your particular machine perform as well as you want it to. How would you feel a couple of hundred dollars later if that were the case?

Many years ago, I had an 80cc Yamaha YG1, considered by many to be one of the finest engineered small two strokes ever built. Certainly it was one of the most popular. Mine was used daily. It was ridden back and forth to the store. It spent its weekends out in the desert or being used as a pit bike at the races. It was always ridden hard and seldom serviced. The only



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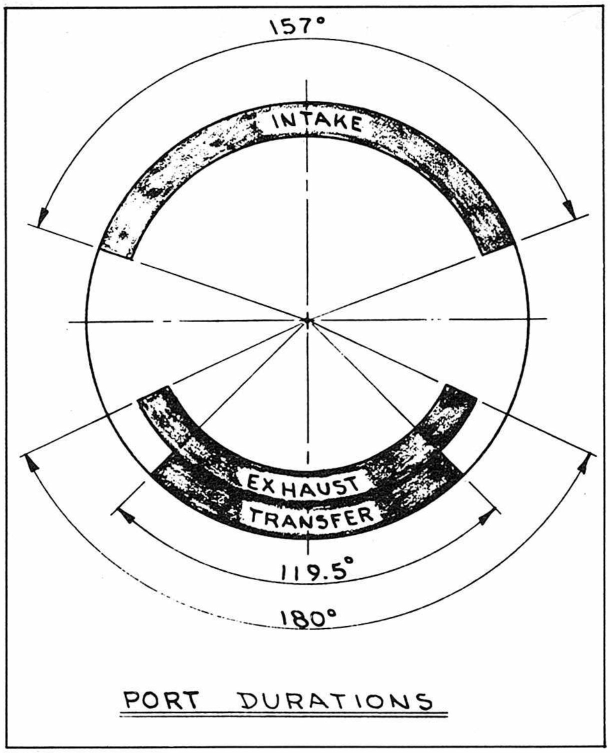
1. While the thought of more power from an existing engine might seem like a cure-all, the type of power needed is an important consideration. A drag racing machine differs greatly from a trail bike and road racer. The power in each case is different. Before any modifications can be made it is necessary to determine just what the machine will be used for. Once that is firm, the proper changes can be made.

2. The first step is to determine the specifications of the standard machine. They will be a guide in improving the performance, and should the outcome not be up to expectations, the engine can be returned to its standard form. This drawing illustrates the opening and closing points of the ports in degrees of crankshaft rotation. One can easily be made for any engine.

3. In some cases, the parts needed to improve performance can be purchased from an accessory manufacturer. Why go to all the trouble of modifying existing parts if newer, proven parts are available? This is the case with many of the popular Japanese machines. An added feature with off-the-shelf hop-up items is the availability of replacement parts if any fail.

4. Before any changes are made it's a good idea to dwell on the principles of a two-cycle engine. It may be simple, but we often overlook simple things and how they really function.



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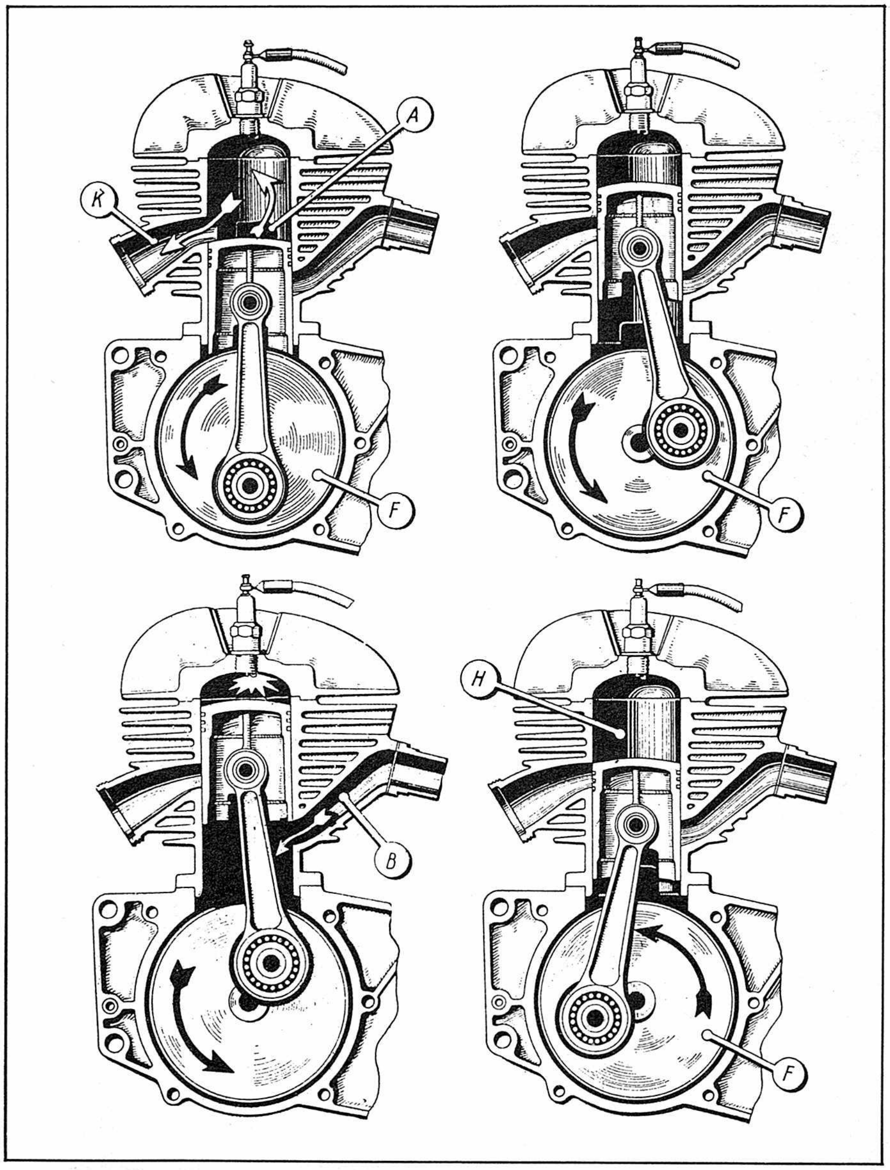
complaint that any of us ever had was the lack of performance. It just didn't run fast enough and could hardly do a wheelie. Then Yamaha introduced the first of their GYT (Genuine Yamaha Tuning) kits, designed to improve the performance of the 80cc engine with a special cylinder, head, piston, carburetor, rotary valve and a sneaky looking chrome expansion chamber, all for $75.00. Once you put it all together you'd have a rocket ship. Our 80 received the works, and boy, did it fly! However, it was no longer any good for running to the store; was no fun in the desert and wasn't tractable enough to be used as a pit bike. It was only good for wheelies, or small bike races on smooth courses. What had been a delightful little plaything had been ruined by the desire for more performance, the wrong kind of performance.

Such an example is not intended to discourage any attempts to improve performance. It can be done, but as any text on the subject will tell you, you've got to give a little to get a little. You can't build a 125 that will run 100 mph and still plonk around the back yard like a trials bike, and vice-versa. There's an entirely different route to both types of performance and few areas that will be parallel. Once the decision is made as to which type of performance is needed, there's no turning back and heading in the other direction.

In either case, whether looking for all-out power or more usable low-rpm



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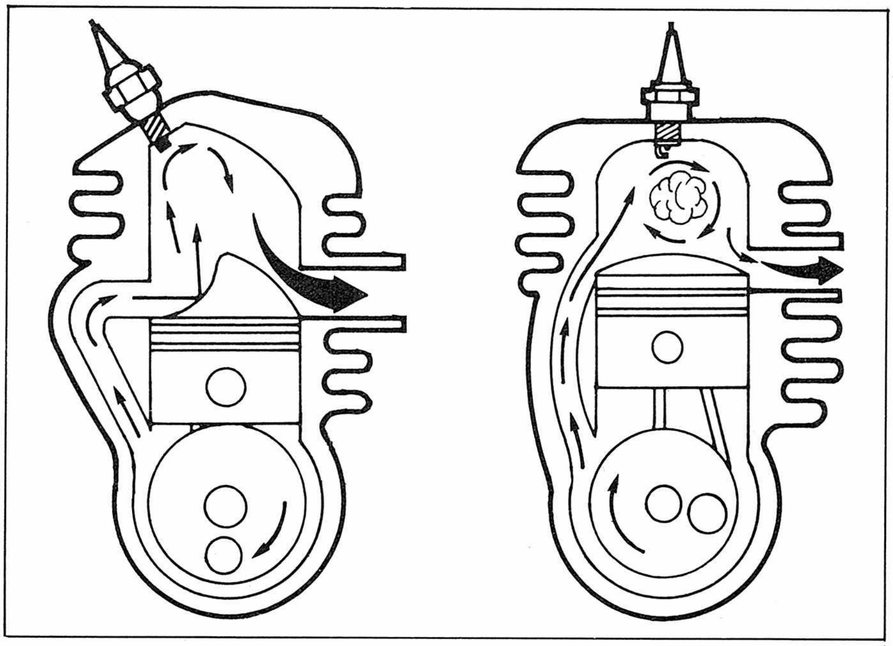

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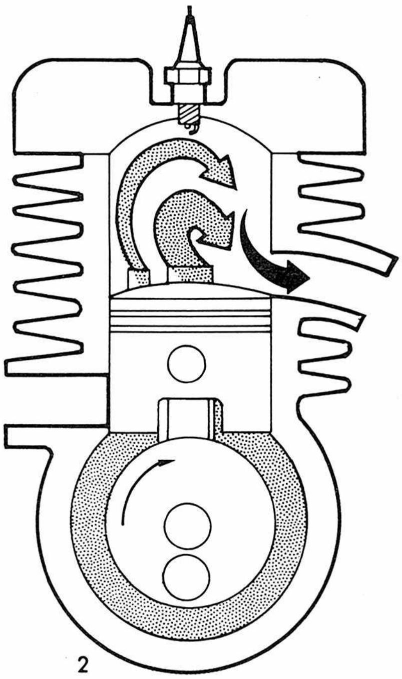
power, we are dealing with the same principles. The performance of any two stroke will be directly related to the amount of air we can flow into engine during the intake cycle of the piston, and the amount of burnt mixture we can push out during the exhaust cycle. If this ideal situation is accomplished at low rpm we will have good low-speed power. If it is accomplished at high rpm we will have good high-speed power. Knowing what we want is easy—accomplishing it is the hard part.

RESEARCH YOUR MACHINE

The very first thing to do is obtain a complete list of the specifications of your machine's engine—bore, stroke, compression ratio, size of carburetor, etc. These are usually easy to come by, and can often be found in a road test of the model or will be in the owner's handbook. A little harder task is to find out the exact port timing, since it will require removing the cylinder to take some of the measurements. If you're fortunate enough to be on good terms with a dealer, his parts man might let you measure a cylinder from stock. If he does, take a look at some of the other parts for your engine since the more informed you are about what's hidden inside the crankcases, the better off you'll be. Measure the center-to-center length of the connecting rod and take a look at the flywheels to see just how many unfilled holes are left by the manufacturer. Find out everything you can, even if it seems unnecessary. Make some little drawings and include dimensions. Somewhere along the way you might want to substitute a piston, rod or other component from another brand and having the figures on hand will make it easy to determine if they'll fit.

Once you've a good list of specs, scan the accessory manufacturers catalogs for specific items designed for your machine. Could be that some, if not all the items you'll need can be purchased. In some instances both the performance and the displacement can be increased at the same time, or as was the case with the old YGI Yamaha, an entire kit may be available from the manufacturer. Explore all the possible sources of new components that can be used, since you can benefit greatly from the knowledge of what has been done even if you choose not to invest strictly in bolt-on items. It is often the easy, if expensive, way to go, but to many it lacks the satisfaction of doing it yourself.

For our purposes we'll assume that there are just no trick parts available or at least none that suit you, and you'll have to do it all yourself. With all the facts and figures you've accumulated, you're in good shape to plan changes and yet still capable of returning the machine to standard if you so desire. Further, we'll assume that you want to improve your off-road machine not build a world-beating drag or road racer. You want a machine that will remain tractable enough to plonk around, but one that possesses the capabilities of going fast and doing the occasional wheelie. To accomplish this, we'll have to deal in three main areas. We must draw more of an air/fuel charge into the cylinder during the intake cycle;



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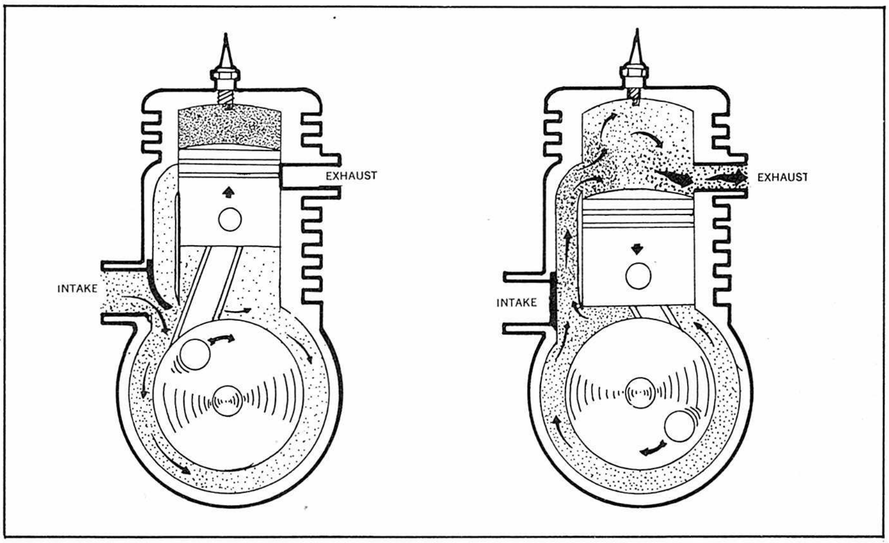

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create a greater push on the piston during combustion; and exhaust the burnt gases out of the cylinder faster once they've done their job. All three must complement each other, for accomplishing any two without the third will not necessarily show any improvement.

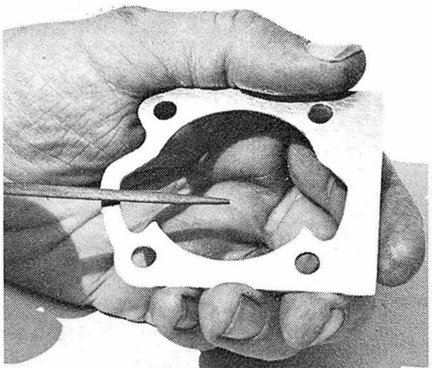
EXHAUST

Since any changes to the exhaust and transfer ports requires work on the cylinder, we'll turn our attention to this area first. Once we've improved exhaust gas exit, we'll look into putting more into the engine. If you can't push it out one port there's little sense in trying to put more in the intake.

One of the simplest methods of improving the exhaust capabilities of an engine is to leave the exhaust port open longer. To accomplish this, we must open it sooner and close it later. However, this is a touchy area, for the earlier the exhaust port opens, the shorter the effective power stroke of the piston. Once the port opens on the power stroke, the power-producing charge is allowed to escape out the exhaust port and with it some of the low-speed power. But it must be done if more horsepower is to be had.

Fortunately, there are ways we can experiment without committing ourselves to a new cylinder every time we want to make a change. The exhaust port height can be changed by grinding the top of the cylinder port opening, then the piston will reach the opening sooner (on its downstroke) and increase the time it will stay open. But it is hard to add material if you find you've taken too much off, there is an alternative that's been used successfully for many years. Instead of raising the top of the ports within the cylinder, we'll raise the entire cylinder by placing a plate between the base of the cylinder and the top of the crankcases. This raises all the ports within the cylinder by the thickness of the plate. By varying the thickness of the plate, the port timing can be changed to suit the needs of the rider. The only work that need be done to the cylinder itself is the removal of an equivalent amount of material off the top. Ten minutes in a lathe will take care of that.

The beauty of such a modification is versatility. Make several plates one millimeter thick, and progressively removing a millimeter from the top of the cylinder. In this manner the exhaust port can be raised a millimeter



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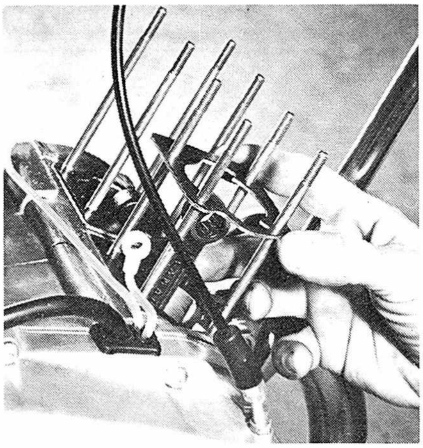

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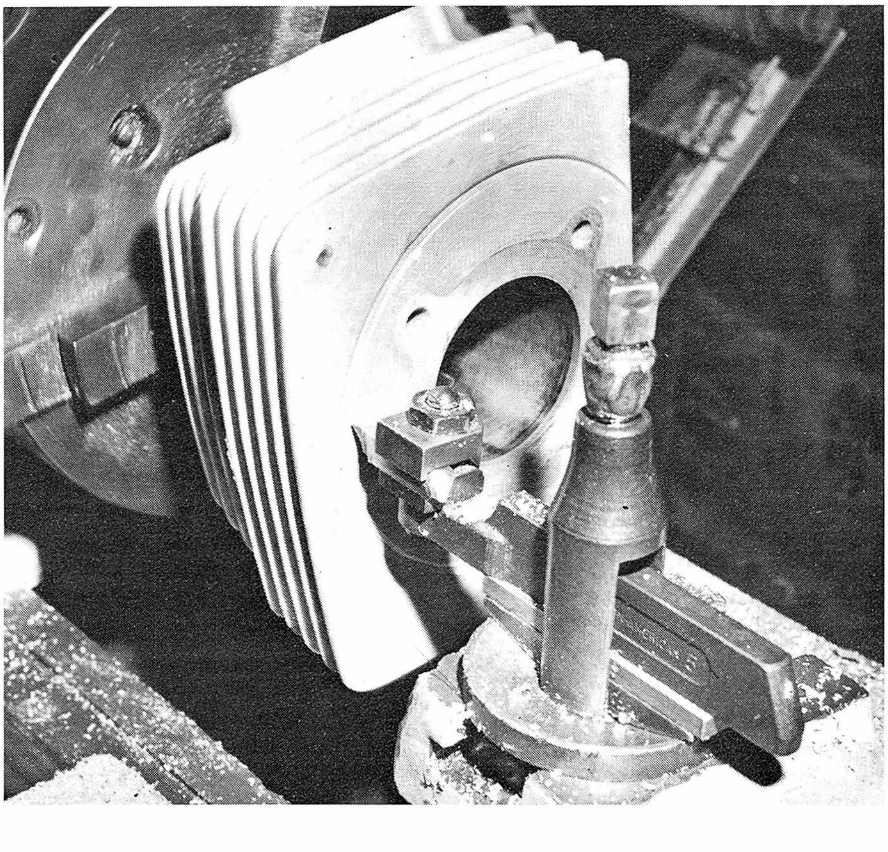

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1. Virtually all modern two-strokes employ what is called the loop-scavange system. Mixture compressed in the crankcase area reaches the combustion chamber by passing through a loop, or port on the side of the cylinder. On early two strokes the mixture was directed by a deflector on the top of the piston. Today's engines aim the mixture with the angle of the port.

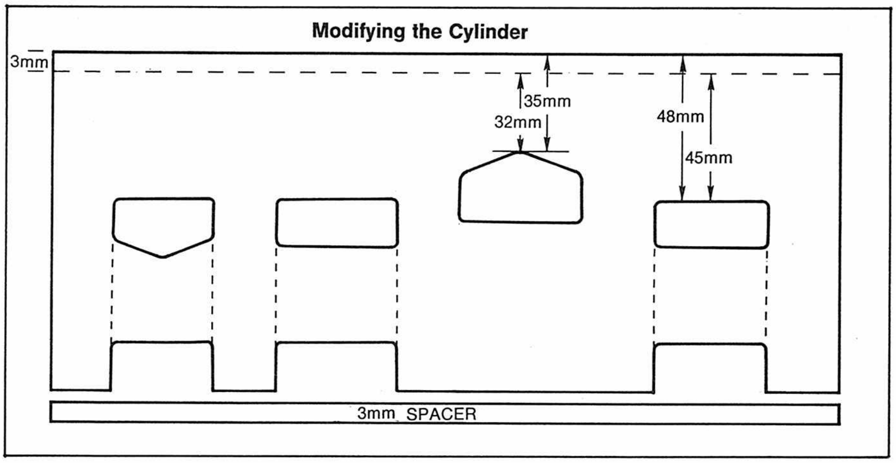
2. Extra ports, called various things from boost ports to 5-and 7-ports, are a simple means of transferring more mixture into the combustion chamber. Properly directed, the added mixture can be used to assist the burned gases out the exhaust port. Much of the improvement in two stroke engines is a result of these added ports.

3. A reed valve is a common hop up item. The valve opens as a result of a change in pressure within the engine and therefore only supplies what the engine needs, when it needs it. Many engines can have reed valves added between the carburetor and intake port. Again, the accessory manufacturers have come up with a number of special kits that will bolt on to existing engines and provide an instant increase in performance for little money.

4. One of the simplest ways to improve performance is to raise the ports within the cylinder by placing a plate beneath the cylinder. The ports will be raised the thickness of the plate.

5. The plate can be copied from the shape of the cylinder base gasket. Made of aluminum, it is installed with a gasket on both sides for sealing. By using different thickness plates, many port timings can be tried. It is best to start with a thin plate and progress to thicker ones after testing.

6. Whatever the thickness of the plate beneath the cylinder, the exact same amount of material must be removed from the top of the cylinder. If it were not removed, the compression ratio would be considerably reduced and whatever improvement the port timing made would be nullified.



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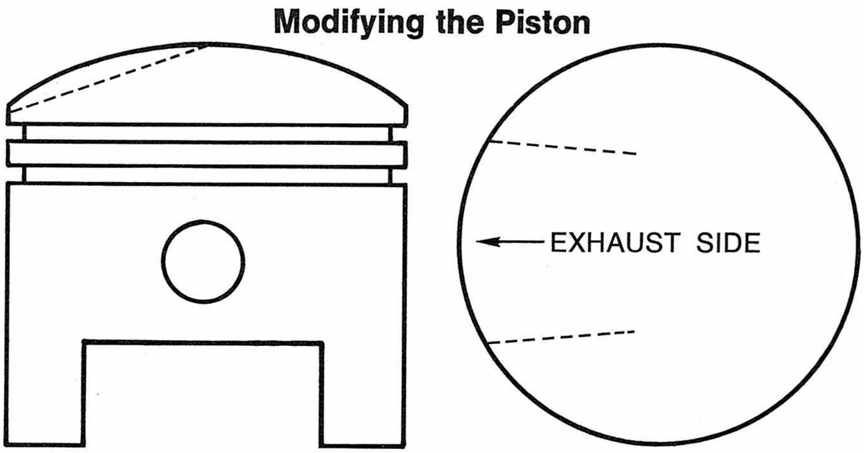

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at a time, and the improvements and changes noted. Care must be taken not to raise it too much. Although the plates can be removed easily, it is hard to compensate for the material taken off the top of the cylinder. A good place to start is at about two mm. Remember, when the plate raises the exhaust port it also raises the transfer ports, and it is possible that the transfers shouldn't be as high as the exhaust. By using the two mm figure we raise them all the same amount and can then effectively raise the exhaust port still further by removing some material off the exhaust side of the piston crown. In this way, the exhaust can be opened a millimeter or more before the transfers, while still only raising the intake ports two mm.

INTAKE

Just as raising the cylinder opened the exhaust and transfers earlier, in the case of piston-controlled intake ports, the intake will open later, providing less total opening time, the reverse of what we really need. One of the reasons we turn our attention to the exhaust first is to avoid modifications to the intake that would be incorrect once the cylinder was moved up by the spacer. With the cylinder spacer thickness now determined, we can go about increasing the opening time of the intake port.

In a piston controlled engine, the opening of the port occurs as the skirt of the piston passes over the carburetor intake opening on the upstroke. The shorter the skirt, the sooner the port opens on the upstroke and the later it closes on the downstroke. With a rotary-valve engine, we have little concern for the fact that the cylinder has been raised and actually have more leeway in selecting the intake timing, since the opening and closing points do not have to be exactly the same as they do when the piston is controlling the intake timing.

As a general rule, we don't want to extend the opening and closing times of a piston ported engine over 25 per cent of the existing opening point of the stock engine. In fact, since the removal of material from the skirt of the piston is a relatively easy task, it provides us with more tuning latitude. A little discretion on the first cut might pay dividends. As with the cylinder, it is a lot easier to take more off than it is to add some on.

To determine that maximum of 25 percent figure, we must establish the opening and closing points in degrees. To do this we can either put a degree wheel directly on the crankshaft and note the exact degrees before and after top dead center that the port is opened and closed; you can make a drawing on paper using the stroke dimension and the port locations that we recorded before we even started to work on the engine. Either way, we will be increasing the duration by removing material from the skirt of the piston until the amount removed results in the desired increase.

It is considerably easier with rotary-valve engines since the valve itself can serve as a degree wheel. By laying the disc on a true degree wheel, it is easy to mark the number of degrees to be removed from the opening and closing edges of the valve. In the case of rotary-valve engines, the opening figure of 25 percent over the existing timing is a good guideline, but the closing point should not be as much. Closing the valve about 20 percent later will not harm high-speed operation and will assist the low end by limiting blowback through the carburetor.

CARBURETION

Now that the intake timing has been adjusted to allow more time for the air/fuel mixture to enter the engine, you must install a carburetor capable of passing more air. Selecting the increase in size is difficult, and depends to some degree on the size of the carburetor used on the standard engine. To obtain an idea of just how big to go, compare the carburetor size of your machine against the one used on known performers of the same displacement. For example, if you have a 125cc machine with a 22mm carburetor and all the hotter 125's are equipped with 28 or 30mm carburetors, it's a safe bet that anything over 30mm is too big. You can put the research of those large manufacturers to good use by just researching their specifications.

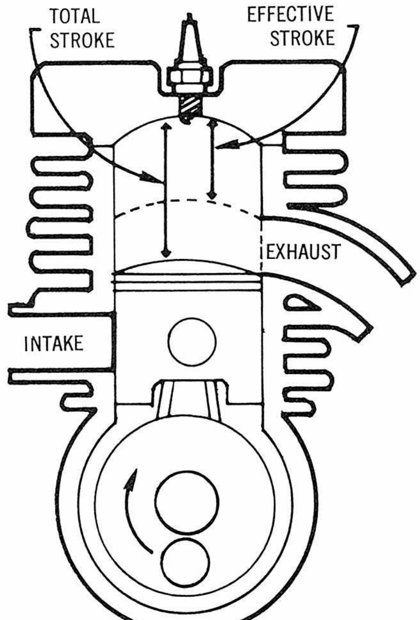
If you're contemplating installing a reed valve intake system the concern for carburetor size is less critical. In fact, a reed valve can perform very well with a carburetor that would be too big on a piston ported engine. The

reed system is really no more than a mechanical intake valve that responds to the pressure and vacuum within the engine.

The reed itself can be made of several materials, but all types will function in the same way. Installed between the carburetor and the engine, it restricts the air/fuel mixture flow into the engine until the vacuum inside the engine is enough to open the reed. The mixture then flows in through the reed. Once the pressure increases the reed will close off the flow of mixture. The reed is a valve just as the skirt of the piston and the rotary disc act as valves, but it is controlled strictly by the pressure differential existing between the inside of the engine and the atmosphere and not by mechanical means. Consequently, the engine only takes the mixture it needs and is less sensitive to carburetor size. Once the pressure increases the reed closes. It's as simple as that.

So far we've concentrated our efforts on drawing the mixture into the engine and pushing it out after it's been used. How do we improve things in that department? What can be done to assure that the increased volume entering the engine will do more work? Whether the mixture enters in the rear of the cylinder as in a piston-port engine, or through the side of the crankcase as in a rotary-valve engine, it will wind up in the crankcase. From there it will travel up through the transfer ports and into the combustion chamber where it will be ignited by the spark plug. How fast it travels, and how much of it passes from the crankcase to the combustion chamber depends on several factors. The crankcase compression, size, number and shape of ports as well as their location in the upper half of the cylinder will all play a role.

The reduction of volume within the



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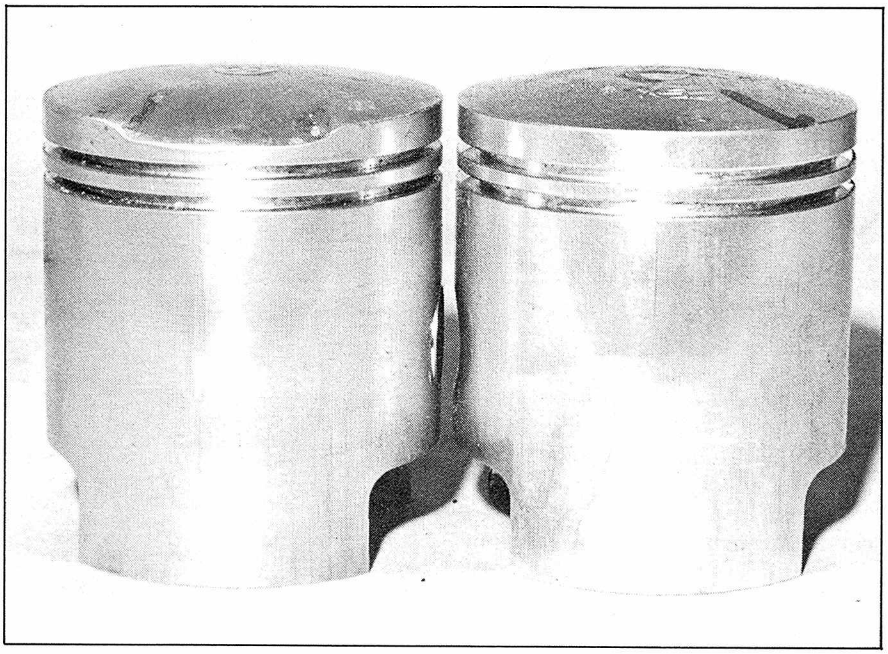
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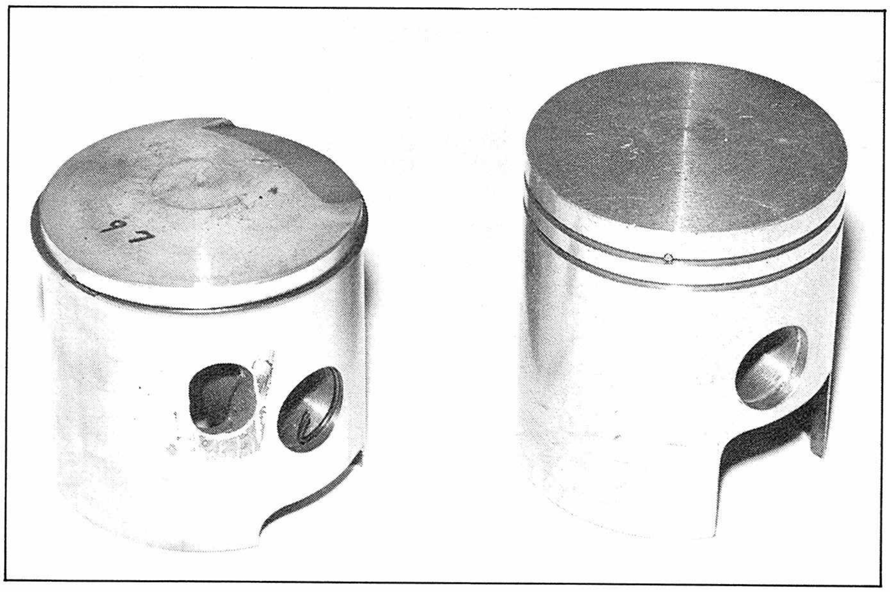
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1. This drawing shows the result of using a 3mm spacer beneath the cylinder and removing 3mm from the top of the cylinder. Each port is raised 3mm without any need to work inside the cylinder with a grinder. All that has happened is the top of each port is closer to the top of the cylinder.

2. Since the transfer ports do not usually want to be raised as much as the exhaust port, the exhaust can be effectively raised even farther by removing material from the exhaust side of the piston. Only a little can come off since there needs to be enough meat between the top of the piston and the top piston ring to get rid of heat created in the combustion chamber and prevent damage to both the ring and piston. If desired, the side transfer ports can also be raised by removing material from the sides of the piston crown. Its an easy experiment to make.

3. Any changes to the height of the ports, whether done on the cylinder or with the piston, will reduce the effective stroke of the piston. Once the exhaust port is opened the power stroke loses its punch. Therefore, the port can get too high and open too soon. As a general rule, machines with good low end power will have a lower port than engines with good high-speed power. The main reason is the length of the effective power stroke.

4. The piston on the left has had material removed to open the exhaust port earlier. Note that only about half of the thickness of the piston crown has been removed to protect the ring.

5. The piston on the right is a stock Yamaha 250cc twin. The one on the left is a road racer. It uses one ring, has the exhaust side relieved and has an added boost port hole machined in the skirt. The hole lines up with a set of ports in the cylinder wall.

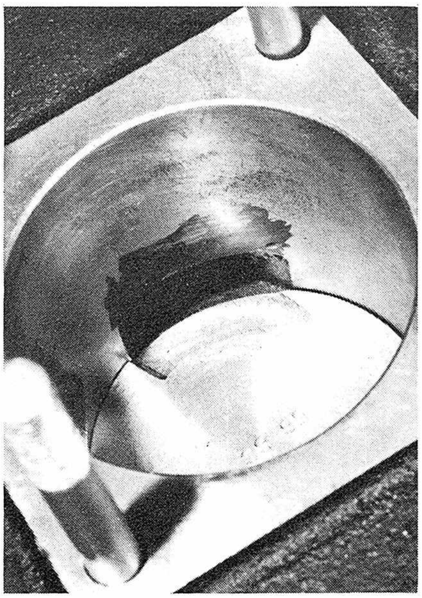
crankcase will increase the crankcase compression. It can be accomplished by filling the balance holes in the crankshaft flywheels with a lightweight material such as magnesium so as not to upset the balance factor. The ensuing increase in crankcase compression pressure boosts the movement of the mixture from the crankcase through the transfer ports and into the combustion chamber. At the same time, it will have a beneficial effect on inhaling the new charge through the intake port and into the crankcase for the next cycle. To do so it increases the vacuum and velocity within the intake tract, virtually requiring the use of a larger carburetor to supply the new demand of the crankcase.

The increase in velocity applies to the movement of the mixture through the transfer ports. The ports should be as smooth and obstruction-free as possible. In many engines, the number of transfer ports can be increased.

Yamaha capitalized on the "extra ports" concept when they introduced their five-port system several years ago. Many manufacturers followed their course, by adding extra ports in existing engines to assist the transfer of as much mixture as possible in as short a time as possible. Extra ports can be added to most engines, but it requires some delicate work with a grinder or access to a machine shop. The variations are many. Some types merely add extra ports. Others grind some grooves in the cylinder and use the piston itself as the inside wall of the port. Still others drill holes in the piston that line up with grooves in the cylinder and benefit from the added ports as well as capturing the fuel mixture that would normally become trapped up inside the piston. They all work, and with suitable modification can be adapted to most any engine.

An added benefit of adding extra ports is the ability to direct the flow of the incoming mixture to the areas that will do the most good. A bugaboo of the two-stroke engine is the fact that the fresh fuel charge is entering the combustion chamber at the same time that the old burnt exhaust gases are leaving the exhaust port. Much of the new charge is drawn out with it while some of the stale exhaust is left behind to contaminate the fresh fuel. There's little to be done within the cylinder to prevent this. A properly designed exhaust pipe will, theoretically, block much of the escaping charge. Additional ports can direct the incoming charge to push out the burnt gases as much as possible, even though some of the fresh charge will go with it. In this way the upcoming combustion phase will take place with a clean mixture, devoid of any of the exhaust impurities.

We have to continually keep in mind the speed with which all these things are happening. In addition to the increased engine speed, we've raised the exhaust port higher up the cylinder so it is now opening sooner than before resulting in a much shorter effective stroke. In many cases, the piston is only going to travel about an inch down the cylinder before the exhaust port opens and the power stroke is ended. The piston just coasts the rest of the way down to the bottom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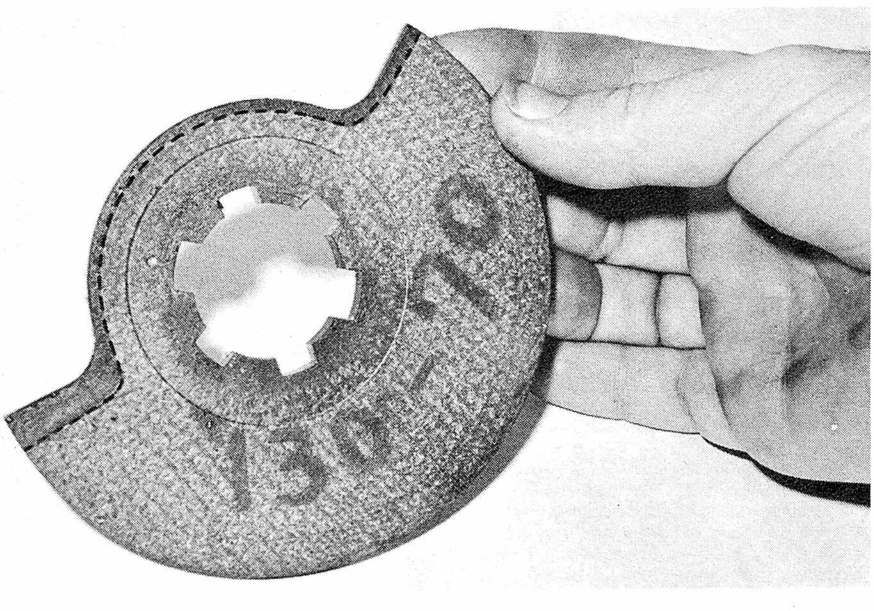
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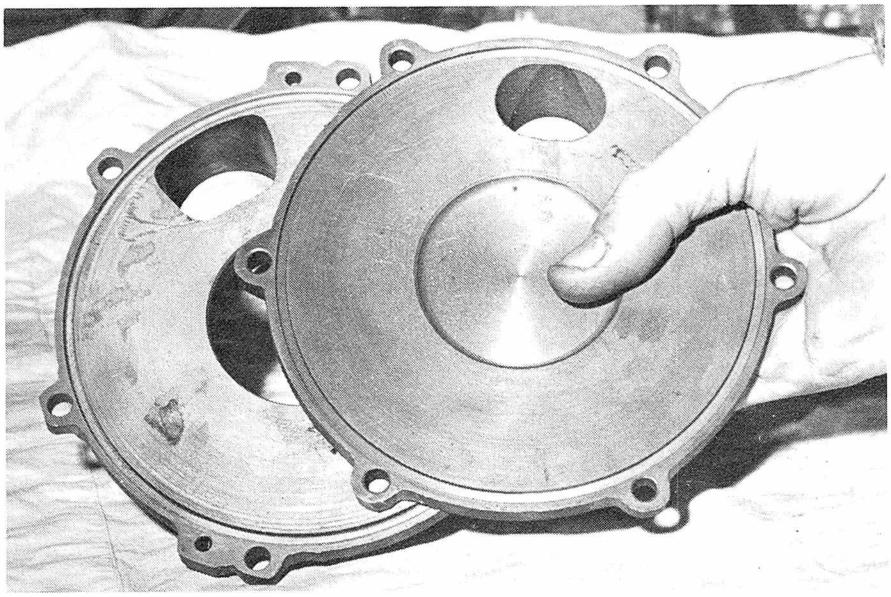
of its stroke. Therefore, the push on the piston during that inch or so is all important. The stronger the push, the better. To increase the pressure of the expanding charge on the top of the piston we must increase the compression within the combustion chamber. This is accomplished by reducing the volume as we previously did in the crankcases.

It is easy to do by removing material from the cylinder head. How much to remove is the difficult decision. Again it usually boils down to a trial and error operation. If we remove too much, the heat that will be created can damage the piston and cause a failure. If we remove too little we are not obtaining the performance we want.

Although the actual amount taken off the head will be measured in inches or millimeters, we must determine the actual amount by volume. Measure the volume of the squish chamber of the head before any modifications, then take about an .040-inch cut in a lathe and measure the volume once again. About a 20 percent reduction is a good starting point. The ideal amount depends on



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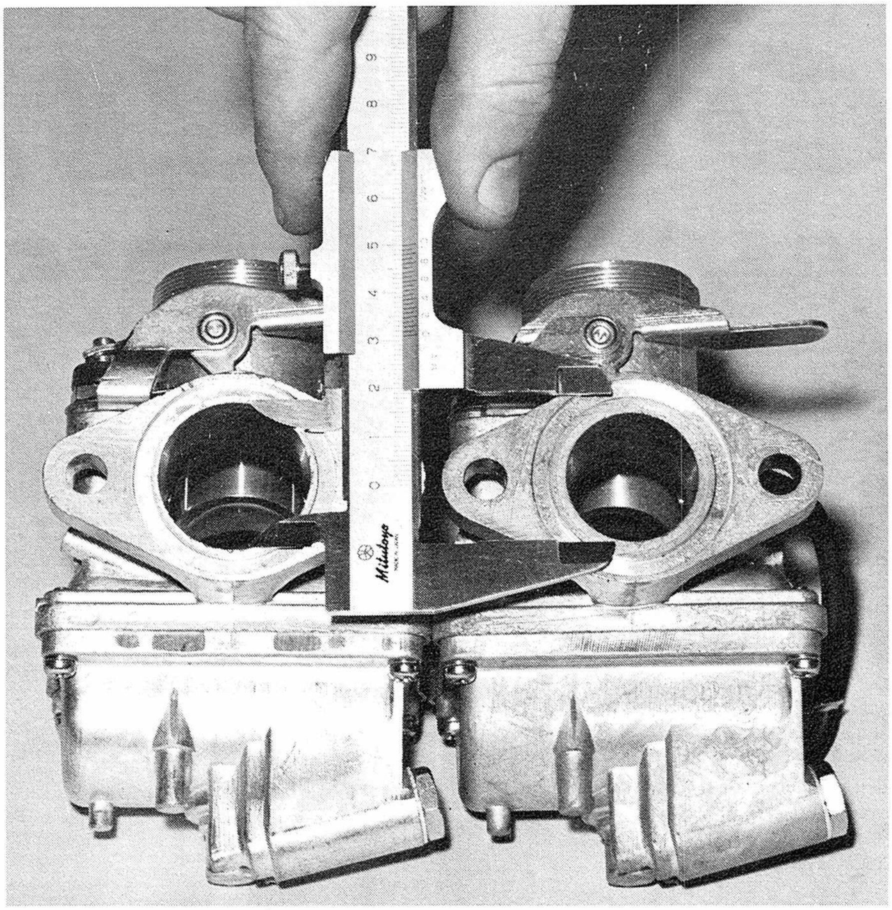

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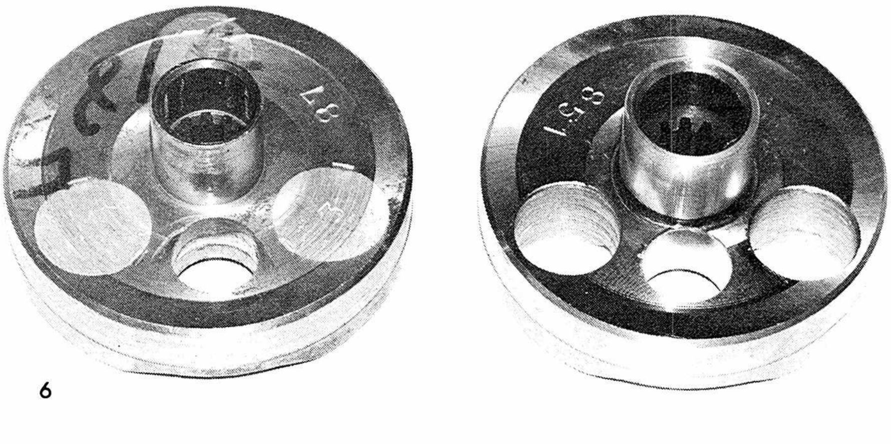

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1. When raising ports within the cylinder it is necessary to have a reference point to determine just how much has been removed. Machinest's bluing works just fine. Note that on this engine the piston has had some material removed on the transfer side.

2. Altering the intake timing on a rotary valve engine is an easy task. Since the duration is to be increased, all that is required is to remove some material from both sides of the cutout. Many accessory manufacturers offer uncut valves for particular models. All you need do is determine the amount to be removed, then remove it.

3. Many rotary valve engines will have valves made of pressed fiber. They can be modified with a file quite easily.

4. Enlargement of the intake port on a rotary valve engine is necessary if the engine is to breathe better. This should be done prior to modifying the valve itself since widening the port opening has the same effect as cutting the valve. Once the port is modified the valve timing can be reached by cutting the remainder off the valve.

5. The enlargement of the cover should correspond to the bore size of the carburetor to be used. Large increases in carburetor size will not always bring large increases in performance. Check the specifications of high-performance engines of the same capacity to see just how big a carburetor they use. This will give some idea of the size needed.

6. Stuffing the balance holes in the flywheels can boost low speed performance but requires splitting the crankcases and disassembling the crankshaft. It may not be worth all the time and money.

things such as the shape of the chamber. If the plug is too close to the piston crown, the engine will likely create some localized heating problems with a 20 percent reduction in volume. If the plug is recessed as some are, the engine could well respond to more than a 20 percent reduction in volume. As with so many aspects of improving two-stroke performance, it's a trial and error process.

You don't know what frustration is until you try and build a tuned exhaust system. There are a number of theories, all dealing with the speed of sound waves and the volume of the exhaust system as related to the displacement of the engine. If we gave you a formula and told you just how to relate it to your machine we'd be doing you an injustice. The only way to come up with the optimum is to bolt your engine on a dynamometer and start making exhaust pipes and more exhaust pipes. That's how the factories do it. As evidenced by a walk through the pits at any motorcycle race, about the only thing they have in common is that they are all too noisy. Two-cycle exhaust systems are guaranteed to drive you mad if you try to figure them out!

If you still insist on creating your own we'll make this suggestion: Buy one of the many available from various component and accessory people designed to fit on your machine and start from there. Many of them are designed with silencing devices incorporated in the stinger pipe, a feature that is a requirement in the riding areas and events. From the bolt-on component you can go in many directions.

In theory, this is how an expansion chamber type exhaust system works. When the exhaust port opens a pressure wave is created by the explosion of the exhaust gas as it enters the pipe. The pressure wave travels down the exhaust pipe at the speed of sound, creating a low pressure area, or vacuum, behind it as it goes. This low-pressure area makes it easy for the escaping gases to follow, or draft, their way down the pipe. When the wave reaches the necked-down area at the end of the expansion chamber, a portion of the wave bounces off the wall of the chamber and heads back toward the exhaust port. The remainder of the wave continues into the tail pipe section with the escaping exhaust gas right behind it. Once it reaches the end of the pipe, it too is reflected back toward the exhaust port as a negative pressure wave.

If all goes well and the pipe shape and length are right on, the first wave, a positive pressure wave, will arrive at the exhaust port opening at just the right time to block the fresh incoming fuel charge from entering the pipe. This will provide the next firing cycle with as clean a fuel mixture as large as possible. The second wave is now coming back from the end of the tail pipe and will ideally arrive just as the exhaust port opens for the next combustion phase. This second wave is a negative wave, so if all is right it will provide the exhausting gases with a low pressure area inside the pipe.

As you can well imagine, making a pipe the exact length to cause this all to happen is no easy task, certainly not one that can be spelled out in a magazine or this repair manual with any guarantee of success. The variables are too numerous to include in a foolproof formula. For example, the speed of sound varies with the temperature of the atmosphere the waves are passing through and the resonant qualities of an expansion chamber will vary with the thickness of the material used to fabricate it. It's a cut-and-try procedure that is aided only by experience.

If you're blessed with patience and a rabbit's foot, go ahead. There are many areas that at first may not seem important, but big performance dividends will reward the attention paid

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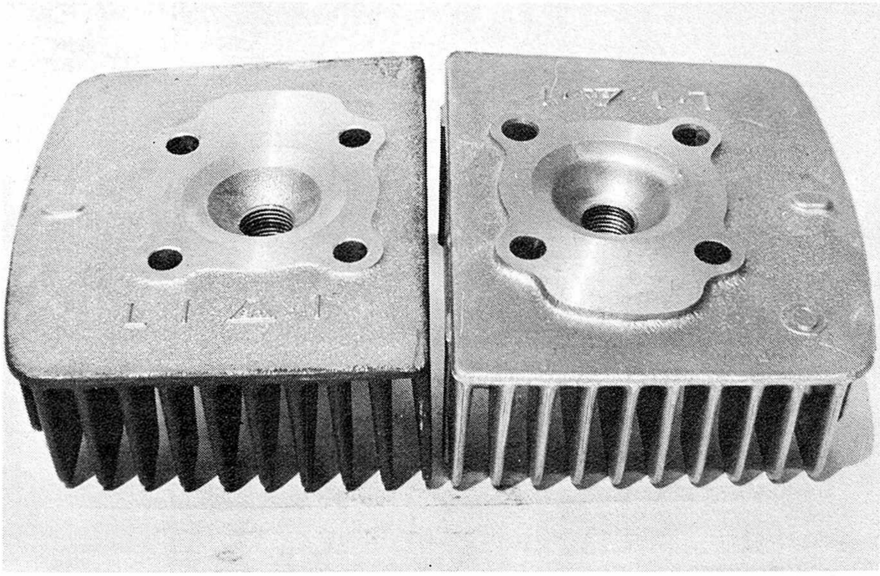

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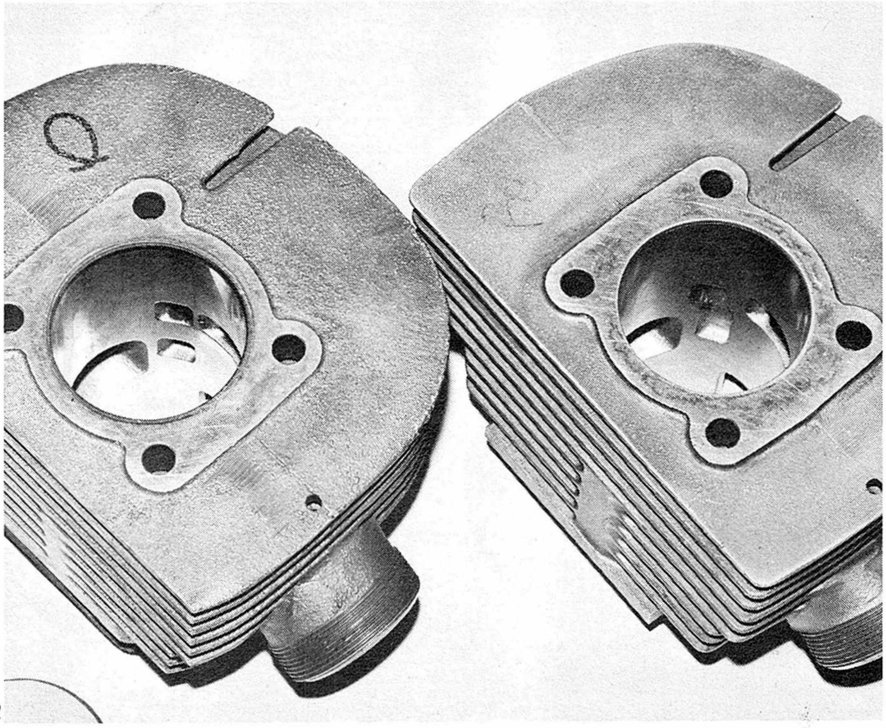

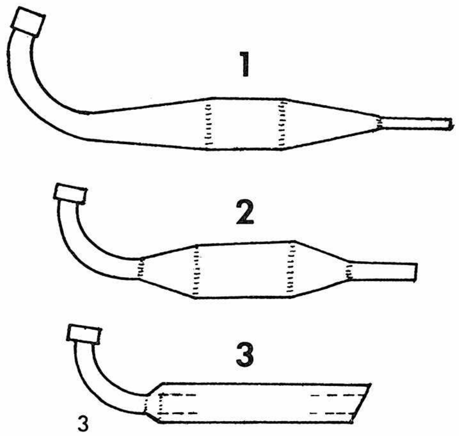

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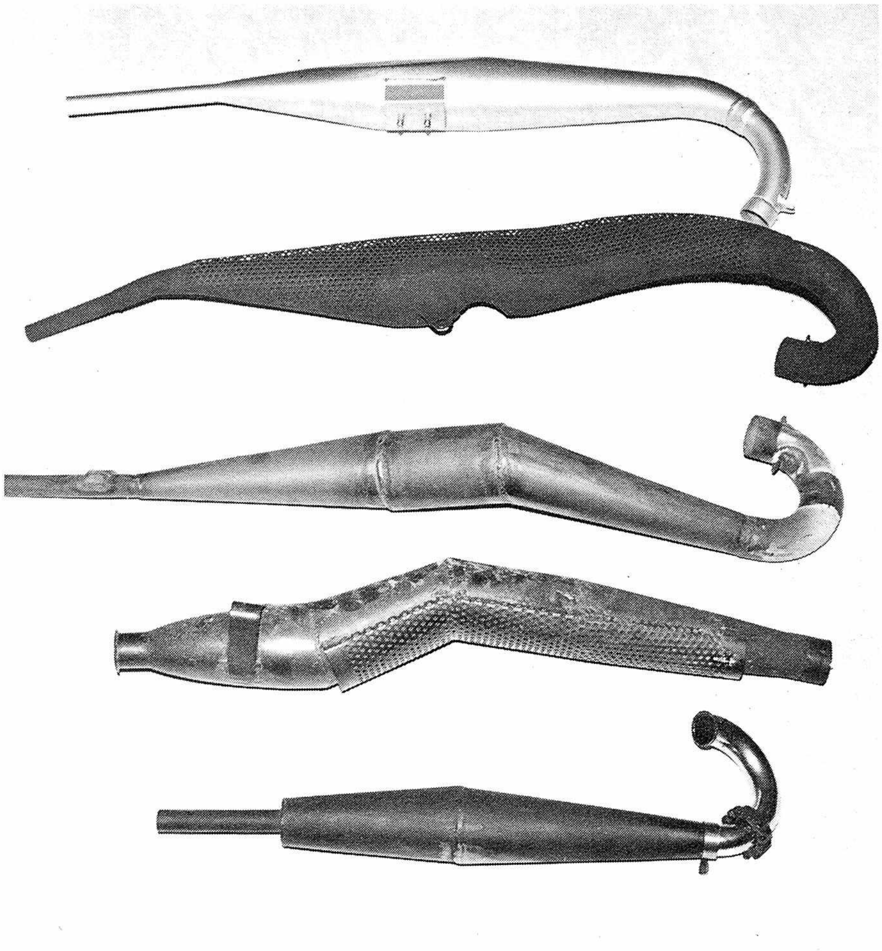
to them. Reducing mechanical losses is like obtaining free horsepower. Good bearings, well lubricated seals, the correct weight oil can effectively result in more horsepower to the ground where it will do the most good. What good is extra power if it's eaten up in turning the engine?

Even the chassis can receive the performance treatment. Chains, dragging brakes and worn out wheel bearings can all rob power. Wherever you look you'll find some area that can be improved in addition to the engine, and in many respects just as important. Read some of the other chapters and you'll see what we mean.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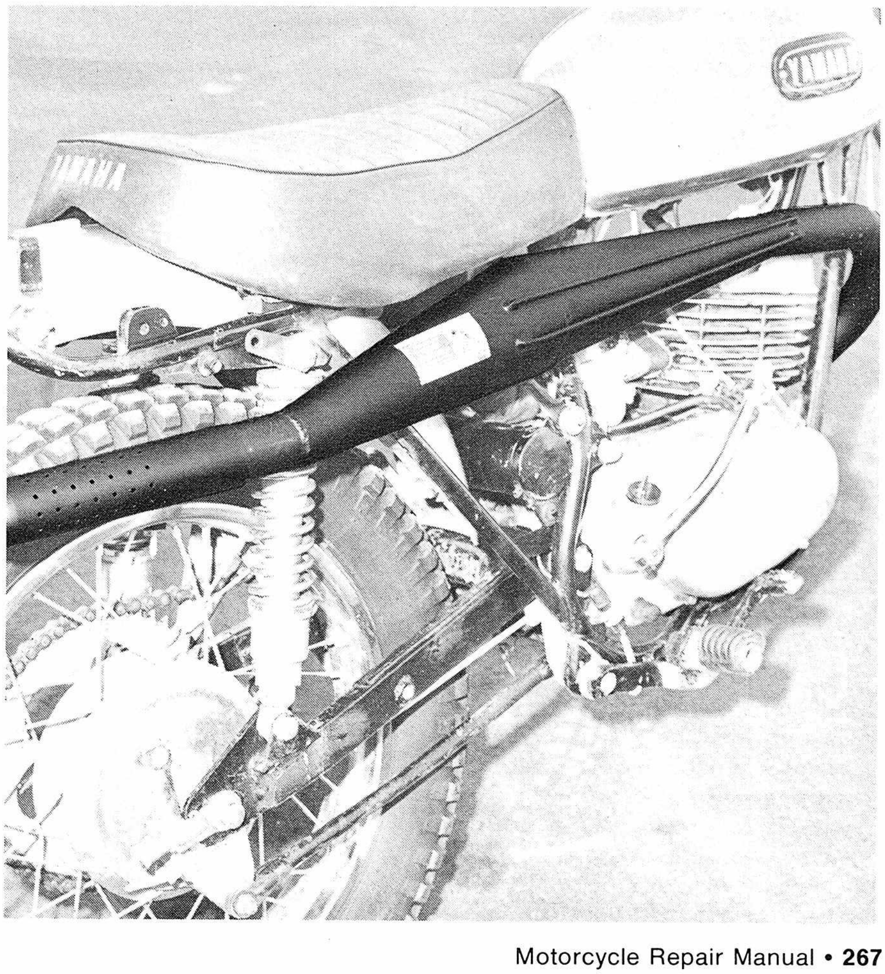
1. Increases in compression ratio can be achieved by removing material from the cylinder head. Combustion chamber reshaping requires welding up the head and having it machined, and is at best a hit-and-miss proposition. The amount removed from the head is another area in which experiments can pay dividends.

2. There are several types of 5-port systems. The one on the right is no more than a groove in the cylinder that lines up with a hole in the piston skirt. The one on the right is a little more sophisticated since it is an actual port. However, both achieve similar results.

3. Exhaust systems are perhaps the most mysterious aspect of two-stroke tuning. The shape and volume of both the main expansion chamber and the exhaust stinger are important but can usually only be determined by dynamometer tests. In general, the pipe at the top will be found on a road racer; the one in the middle on an off road machine like a moto-crosser; and the bottom one on a street machine that requires silencing.

4. They come in all shapes and sizes. It is really a cut, weld and try procedure that accomplishes the most. Again, take a look at some existing pipes and try and come up with one that seems to work on a high-performance machine of the same capacity. That's after you've tried all the accessory manufacturers.

5. The accessory people are the best bet since many of them have tried their pipes under both race conditions and on the dynamometer. This one from Bob Bailey has a built-in silencer in the stinger.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FOUR-STROKE HOP-UP

Empirical parametric optimization directed at the maximization of kinetic utilization of viable thermodynamic processes

BY BILL OCHELTREE

What the hell do you expect out of an aerospace engineer who spent most of 22 years dealing with military hardware? What that sub-title says, is: practical combination of variables to yield the greatest possible mechanical power from the heat of controlled burning (of fuel). The key word here is "practical." Theory is nice, and in truth it works; but the variables often work against each other so that in practice we are stopped short of theoretical goals. What we will talk about here are some practical adjustments to the remaining variables in a production four-stroke engine which may sacrifice some of the original designer's goal in order to further approach the goal of maximum power output.

Keep in mind that we are talking about something that already exists, and that changes must be confined to the limits within which the engine exists. The first thing is that everything we have to work with at present is the same as far as basic principles. All motorcycles have internal combustion engines utilizing a piston, rod and crank. The only variables that may be altered here are size, and the limits are rather narrow.

KNOW YOUR ENGINE

The features which make four-stroke engines distinctive in basic principle are in the combustion chamber and the way in which the air passes in and out. Head, valves and ports are the variables; and though size is a limiting factor, seemingly minor differences in configuration can have major effect on power output. Granted, engines don't look alike, but what goes on inside is pretty much the same. Differences in appearance and arrangement account for differences in the manufacturer's goals. There is no perfect design. It all depends on what the designer considered most important: Cost, reliability, maintainability, room for growth. One good feature in an engine usually means the omission of another. You simply can't have it all.

There are two basic things in yielding more power from any given engine: Burn fuel at a faster rate or draw more out of what is burned. Burning at a faster rate can be approached from two directions: Put more fuel (and air) into each cycle, or increase the number of cycles.

Obtaining more usable energy from the fuel that is burned is a matter of increasing thermal and mechanical efficiencies. Putting more fuel into the cylinder is possible with greater displacement or increased volumetric efficiency, and higher rpm of course means burning it more often. If you're seriously considering modifying an engine for more output, you have probably already considered some of the several ways, so let's concentrate on the practical limits.

The first things to consider are physical size, shape and weight of the various engine parts, the way they fit together, the amount of space they have to move in, and what they are expected to do. What this all boils down to is a matter of measurement. In the bike service manual they are called specifications, but usually the only things listed are those which are

1. Here in the R&D facilities of Webco Inc., speed accessories are tested on the dynamometer before they are offered in their catalog.

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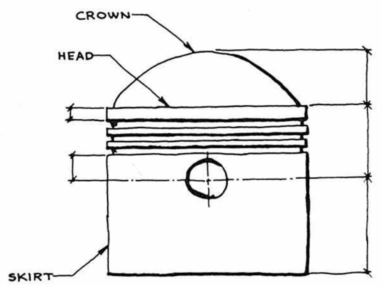
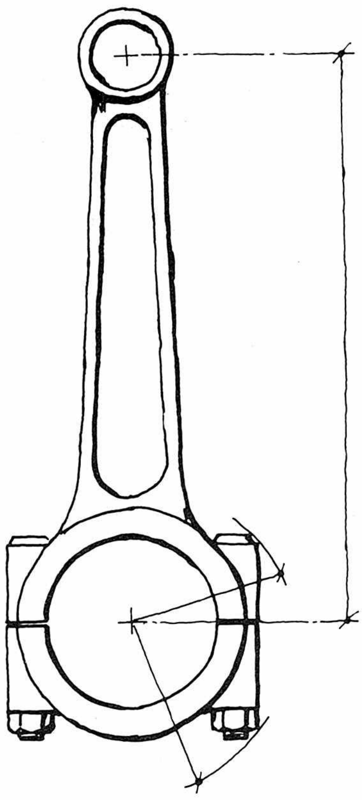
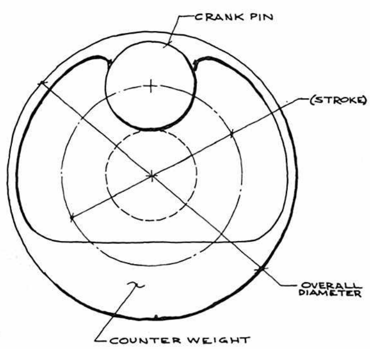


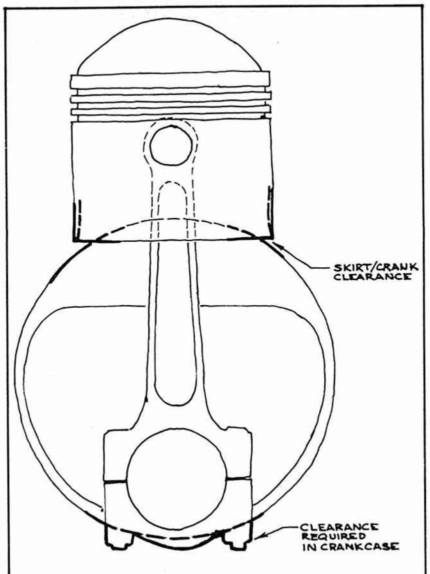
SKETCH #1
KNOW YOUR PISTON!



SKETCH #2
AN IMPORTANT CONNECTION



SKETCH #3
YOUR CRANK MAY NOT LOOK LIKE THIS, BUT SOME PART OF IT SWINGS AN OVERALL DIAMETER.



SKETCH #4
THE WHOLE . . .

necessary to restore the bike to stock condition. Many of the things that have to be known about an engine before undertaking any changes can only be found on the engineering drawings used to build the engine. Manufacturers are usually reluctant to give out such information freely, so the only way to obtain it is to measure it yourself.

Intimate knowledge of every detail in an engine's design is the most important asset to a successful tuner. It's impossible to know how far you can go unless you know where you're at. The included sketches will give you some idea of the various dimensions of parts that are needed before any changes can be made. Of course, when you go to buy such items as pistons, valves, springs and guides you'll be told that they will fit your engine. Don't you believe it! Not that the dealer is lying, but many parts will fit various different engines with minor modifications. Without those modifications, it could mean instant junk, so you better know just exactly what you want before you start. It'll save a lot of chasing back and forth.

TOOLS

The first thing you'll need for these measurements is a basic set of tools. Things like micrometers, bore gauges, surface plates, etc. aren't really necessary except in the machine shop. Let's assume you'll have all your machining done outside, so all that's really necessary are those items needed for the work you're doing. The most important instrument you'll need is a dial indicator with a stand and some clamps and adapters. A half-inch range indicator is minimum, but a one-incher is a lot more usable. The next thing is a vernier caliper. Don't try and save money here; a $2.00 vernier just doesn't make it. In addition to these basic precision measuring instruments you'll need machinists calipers: inside, outside, and hermaphrodite; machinist's combination square, level, six- and 12-inch steel rules, feeler gauges, radius gauges, and a scribe. Once you've priced out these items you'll see that it's a sizeable investment. That's just what it is—an investment. Engine hop-up is a world of its own and it takes time, money and patience to derive any satisfaction from it.

A few other items you'll need in your shop are: a chemist's precision liquid measure, a burette is handy but a graduated beaker will do (100 cc size); a good scale, two- to five-pound capacity in grams or at least tenths of an ounce; a degree wheel; compression gauge; and a spring scale for checking valve springs. Last but not least, don't ignore the service manual for the engine you'll be working on! For that matter, find as much information as you can. Distributor's and manufacturer's catalogs have a wealth of data and ideas, and when in doubt, ask. Your bike dealer knows what's available and where to have things done.

CLEANLINESS IS NEXT TO . . .

Well, the place to begin is with engine tear down, and the first and best rule is: order and sanitation. Keep it clean and neat, and even if you blow it you can say it came from the cleanest shop in town! One nice thing about bike engines is that they don't make any V-8's—yet, but a twin and especially the fours can produce a lot of loose parts, so some boxes and coffee cans will make the job of finding things a little easier. Another thing: Make sketches and keep notes, they're a great aid to ponderous thinking on the john, and along with a six-inch steel rule they'll eliminate a lot of guesswork when you're out shopping for parts.

THE CRANK

The importance of piston, rod and crank dimensions are pretty obvious when you look at the entire assembly. The clearance between the piston skirt and flywheels always comes into

consideration when going to a new type piston, and the other points shown come into play on a stroke job. Increasing the stroke of an engine is a major task which is limited by the size of the crankcase. All that's needed is a little more distance between the crankpin and shaft, but that leads to a lot more. Crankshaft rework requires the services of a good machine shop to build up and regrind the crank pins, then the right piston and rod combination has to be found. Crankcase clearances must be checked and most cases don't leave much meat to hog out. The crank, of course, will need rebalancing, and this may mean adding material to the flywheels. There's a lot to it and sometimes the cost isn't justified by the results.

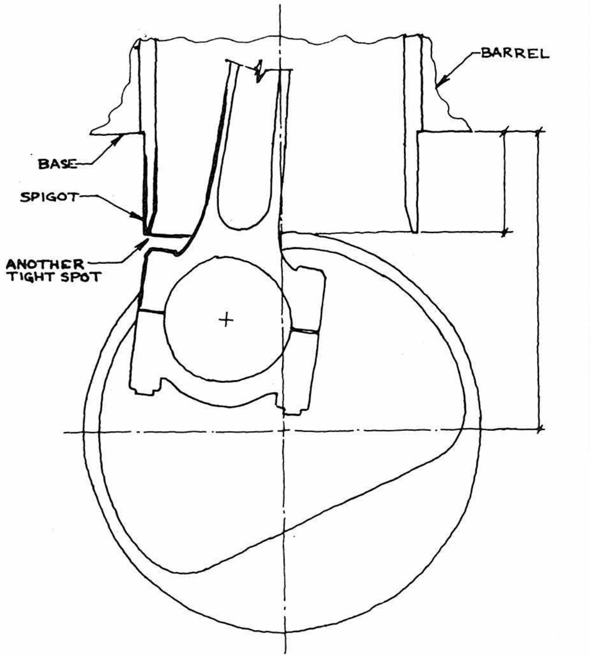
HEAD, VALVES AND CAMS

Valve and related measurements are illustrated. These are very important when making cam, spring, guide and valve changes. Valve lift and piston clearance shown in the accompanying drawing are the critical operating dimensions between the head and cylinder. Valve lift is measured with a dial indicator at the spring retainer. Piston clearance can be calculated from a series of measurements, but the easy way is with a piece of clay. Don't forget the head gasket when removing and replacing the head to take measurements.

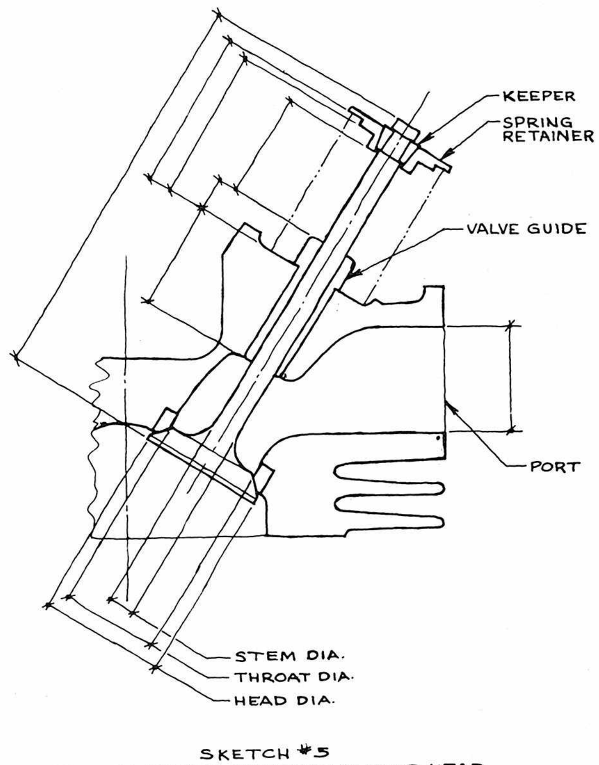
Valve timing is one of the biggies, so you might as well practice measuring your stock timing during engine tear-down. First of all you'll have to mount a degree wheel to the crankshaft and attach a sheetmetal or wire reference marker somewhere on the engine near the edge of the wheel. The head will have to be removed so that TDC (top dead center) can be located from the piston using a dial indicator. Rotate the crank to bring the piston up to the top and clamp the dial indicator in place. Locate the indicator so that the plunger is at about one-half of its full travel distance. Now rock the crank back and forth to get the maximum reading on the indicator; this puts the piston at TDC. Next, adjust the position of the degree wheel to line up a 0° mark with the indicator. To check the set-up, rotate the crank both forward and backward an equal number of degrees; the dial indicator should show identical readings in both directions.

Once you've established TDC, make sure the degree wheel is securely mounted. There's nothing like having the degree wheel come loose after buttoning the head down! With the head back in place set the valves at the manufacturer's timing check clearance. If he doesn't specify one, use .020-inch, and be sure all valves are set as nearly the same as possible to obtain consistent readings. The dial indicator is then set up to contact the spring retainer with the indicator plunger pointed in a direction parallel with the valve stem and pre-loaded to within about a half dial turn of the end of travel. Set the indicator dial at zero and turn the engine through a complete cycle and note the maximum dial indicator reading. This is the valve lift. Upon completion of valve travel, the indicator should have returned to the initial zero setting. Now rotate the crank slowly forward and note the crank angle when valve movement just starts, and from this point record the amount of valve lift for each 10 degrees of crank angle through the entire travel of the valve. Doing this with all the valves will give you some idea of the accuracy to which cams are ground and installed in production engines. Don't be alarmed if differences of up to 5 degrees in opening and closing times between cylinders occurs. This is where care and patience come into play in setting up for performance.

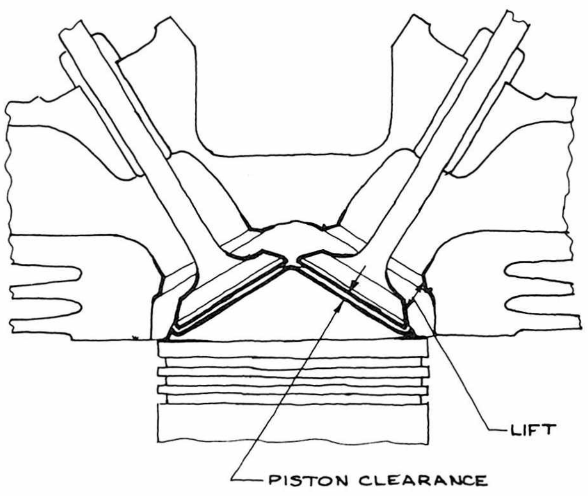
You can also check yourself if there is a difference in lift of more than .005-inch between cylinders make sure clearances are the same. A



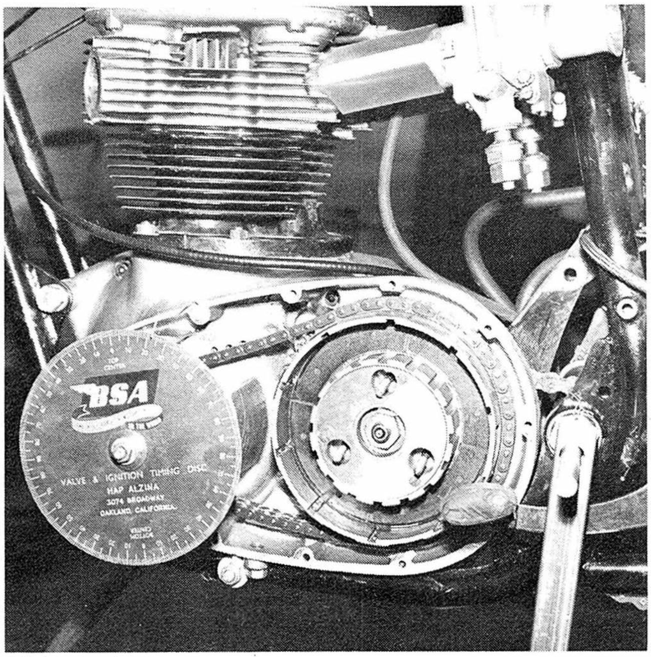
SKETCH #4A
. . . THING



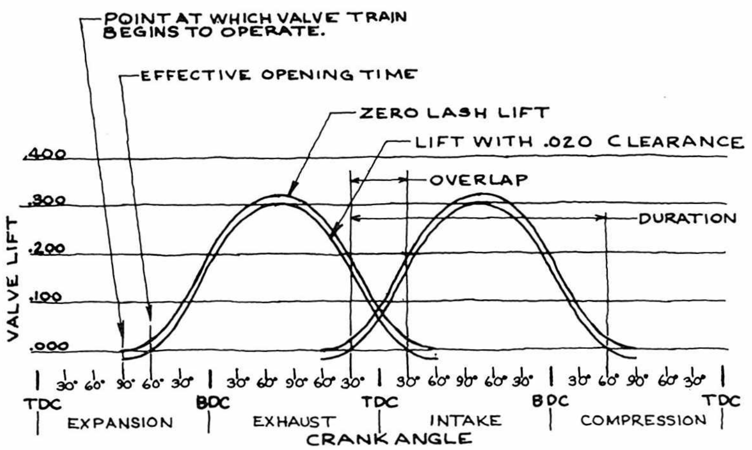
SKETCH #5
GETTING THINGS STRAIGHT IN YOUR HEAD



SKETCH #6
IGNORING THIS HAS CAUSED
MANY A HEADACHE.



1. **A degree wheel securely mounted on the crankshaft and a firmly attached marker are the first steps in checking valve timing.**



SKETCH #7
TYPICAL VALVE LIFT DIAGRAM
(BE THE FIRST ONE IN YOUR NEIGHBORHOOD TO MAKE YOUR VERY OWN!)

slightly greater lift on the valve of one cylinder over another should be accompanied by a corresponding increase in duration. For that matter, differences in lift should be consistent throughout complete cam rotation. The reason for this is that cams are generally ground from the same master template and the only differences should be in overall timing due to indexing variations. When this occurs all that can be done is to split the difference between cylinders, but with a good custom-ground cam this rarely occurs as they are usually indexed within one degree. By the way, the reason cams are timed with a clearance much greater than the running clearance is that what really counts is the *effective* opening time. The first and last .015-inch or so of valve opening has little effect on gas flow; for all practical purposes the valve is closed. Also, even in the best of cams there are variations in the *ramp* area, the transition between the *heel* of the cam, where no movement of the lifter occurs, and the *flank* which is the actual lifting surface.

ACTUAL VOLUME

Now that you know your cam characteristics then you can begin to consider what sort of changes in timing, lift and duration may be of benefit. One more thing though, before running out to buy a cam, and that's compression ratio. Again, this is another starting point to be surveyed and staked out so that you know which way and how far you can go. Compression ratio is the ratio of the volume of the maximum space which may be filled with air in the engine to the volume of the space into which it is squeezed for the burning of the fuel. A compression ratio of 9.0:1 means that the space available for air in the cylinder is nine times as big as the space that it is compressed in. If you see this very clearly then you know that the displacement is eight times the volume of the combusion chamber, right? If you didn't know that, but you know that eight does not equal nine, then consider that eight units of volume in displacement plus one unit of volume in the combustion chamber equals nine units total. Mathematically:

Compression ratio = (displacement + combustion volume) ÷ combustion volume.

Here's where the chemist's burette or graduate is used. Carefully measure a quantity of light oil, kerosene or automatic transmission fluid and fill the combustion chamber as shown in the illustration. What's left in the container subtracted from the amount you started with is the head volume, in cc (cubic centimeters). To convert this to cubic inches, multiply by .061 or divide by 16.4. Add to this the volume of the head gasket opening which is the thickness times the area. If you have a flat-top piston, then subtract the volume of the portion

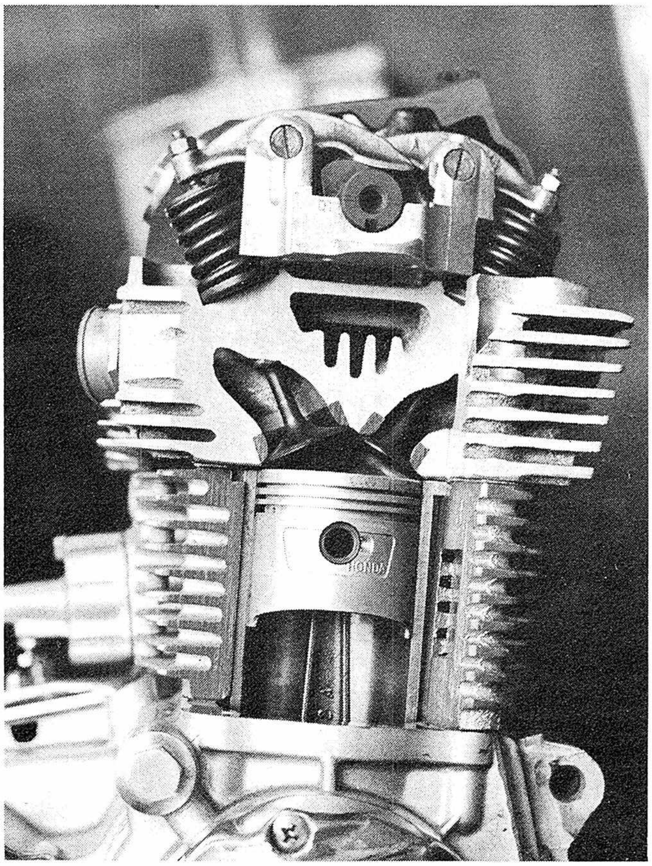
which protrudes above the cylinder at TDC or add the volume of where it falls short of the top. You now have the combustion chamber volume and can compute the compression ratio. Don't use the displacement given by the manufacturer, measure the bore and stroke the calculate the actual displacement. Position the piston at a measured point below the top cylinder surface and measure the volume indicated. Add this to the head and gasket volume and then subtract the partial displacement volume generated by the stroke 'D' shown in the sketch. This then gives you the combustion chamber volume. While you're at it, cc the heads for all the cylinders. If they're not all within a couple of cc's of one another you'll have some extra head rework to do. Make sure the cc differences aren't due to valve seating variations.

One more thing in the measurement category: weigh any moving parts you are likely to replace to the nearest gram or tenth of an ounce (28 grams to an ounce). This includes piston, rod, pin, rings, valves, springs, rockers, pushrods and lifters. Any piston /rod/crank changes will affect balance, and any valve train changes are very important to the valve grinder to help you select the right springs.

OKAY, LET'S GO AT IT

Well, now that you know your engine inside out, it's time to make some decisions. Once you've made them, then you can make some fairly intelligent guesses at what to do to your engine. The first thing is time and/or money. If neither one is an obstacle then forge ahead, but if you're a little short then read on and do plenty of shopping around. Next what do you want the power for? Land speed records, drags, hillclimb and speedway demand the most to be competitive; cost per mile is the greatest. Mile, half mile and road racing is where the big money is; but here engine reliability ranks almost equal with power, so there's a lot of compromises to be made and a whole lot of maintenance. Motocross and TT is where an engine takes the most pounding; gobs of torque and plenty of strength are what's needed here. Hare-and-hound, cross-country, enduros and just plain fun riding require the maximum in reliability with a broad, smooth powerband. Basically what we're discussing here is the yielding of more power from the engine, but our Grand Vizier, Bob Greene, reminds that in considering what the engine will take by way of modification, close attention must be given to what the rest of the bike will take. Clutch, gears, chains, sprockets, wheel spokes, bearings, chassis strength & geometry, and brakes all have their limits, and quite often a manufacturer will allow less margin of safety for these parts than for the engine. Often a mildly hopped-up bike will start to blow clutches or gears and things like engine mounts will shatter when they have to handle a lot more than they were designed for. Not only is care required in engine rework, but thorough investigation of the entire bike should be undertaken to reveal any possible weak points which may have to be beefed-up to cope with more power.

The most critical decision to be made is that of displacement. Size and cost go hand-in-hand and this is the usual basis for the beginning. The real decision though, is an emotional one. How much horsepower can you



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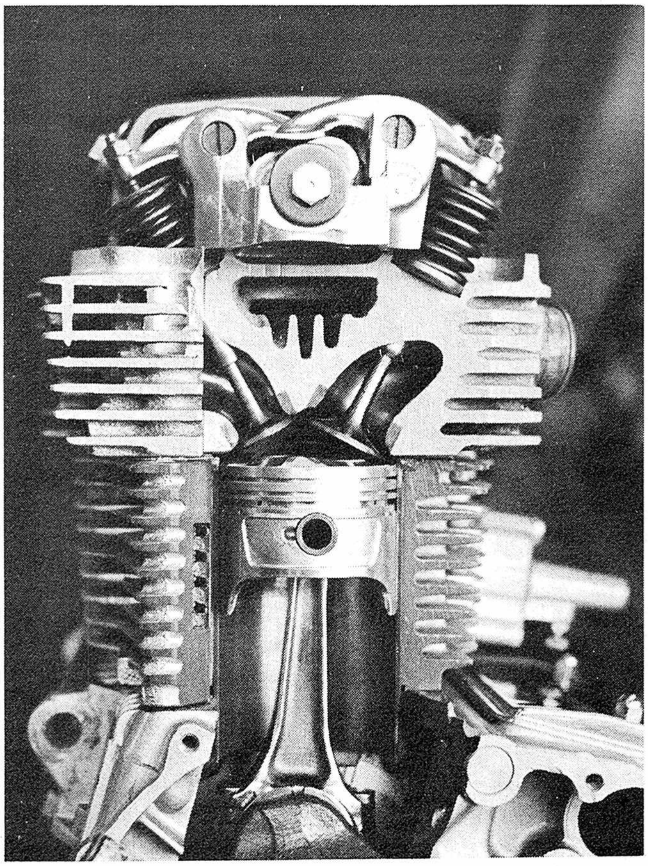

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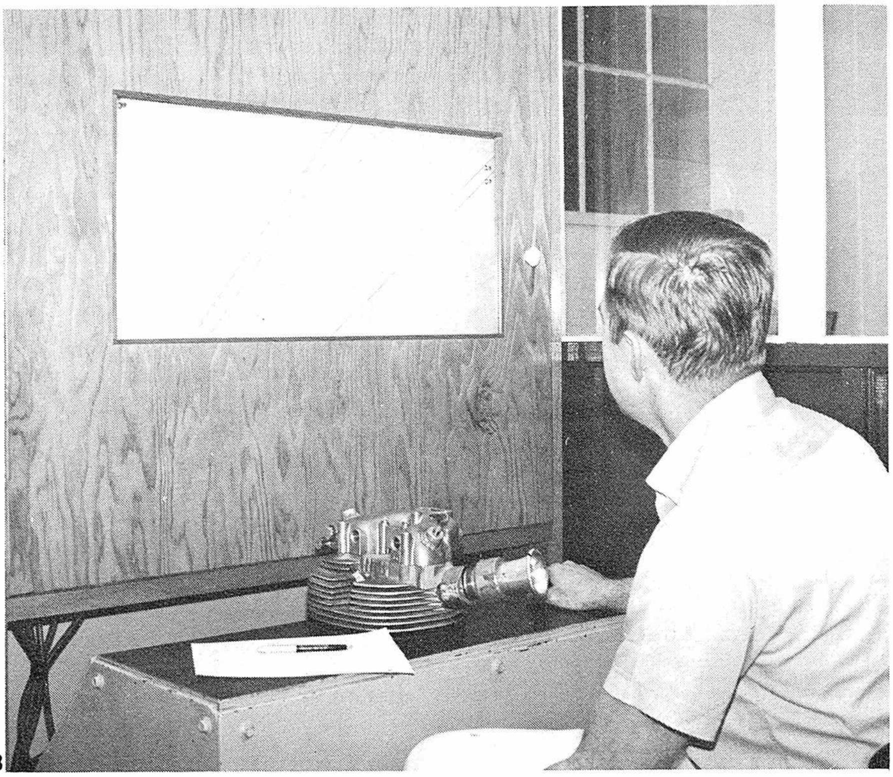
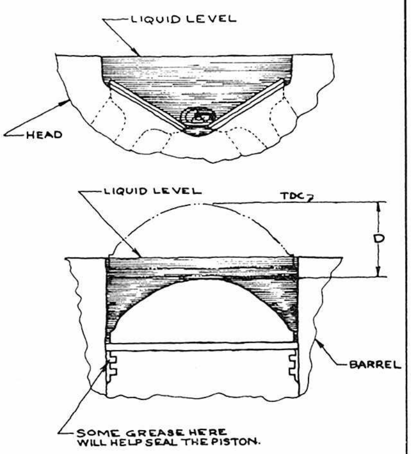
1. This is the "stock" end of the 750 Honda display cutaway built by Action Fours of Santa Ana, Calif.

2. Here's what can be done with an engine. Note the ports, valves, dome piston, "hard face" build-up of the cam, polished rod and the thickness of the cylinder liner after boring.

3. Super-tuner C. R. Axtell uses the air flow technique for checking out the effectiveness of port and valve modifications.

3





SKETCH #8

A VOLUMINOUS TASK

really handle? Can you really use all that power that you're sitting on? The more power you apply to the rear wheel, the faster you go, and the faster you go, the more your sweet little fanny is in jeopardy. Kind of silly to buy more than you need, right? What's the matter? Afraid to turn it on? Then there's the hassle of dirtying up your hands, chasing parts, laying out the bread for special tools and working till 3:00 o'clock in the morning to be ready to go at 8:00. Guess these little bikes just can't take it, can they. Parts are cheap enough, but the way you have to run it wide open all the time, it seems like you're tearing it down every week. Nothing like a big old good one or a good old big one, right? They run forever and when you need the power it's right in your hand. These are some of the emotional arguments for and against.

Now let's take a little more rational look at it. Let's face it, a 90cc Honda bored and stroked to 150cc still won't run through the dust of a 250 Pursang, but the inside of the crankcase may see daylight from a funny angle after trying. A 20 percent increase over 11 horsepower may not feel like a kick in the pants, but it will shave three or four seconds off the time around your favorite test track and that can mean a lot in competition.

What you really have to consider is yourself, and what *you* really want to do. If you want to start hopping up engines just as a hobby, remember that time spent in the shop is time that could be spent riding—it's a decision that only you can make. If you decide that you really prefer to putter around in the garage and you're on a limited budget or want to do a lot of experimenting, then start small. Engines up to around 175cc are easiest to work on and parts aren't too expensive. If on the other hand, you really dig riding and like the feel of power then don't hesitate to spend a little more now for a size that suits you, it will save money in the long run. When you feel as though you're pushing the bike to its limit, then look at hop-up as a means of increasing reliability and providing just that little bit extra to get the jump on the competition. Any of the top riders and tuners will tell you that once your riding ability is in the same league with the hotshoes, then all you need is just enough horsepower to win. If you're consistently running in the back of the pack, don't blame it on the bike. If, however, you are consistently being nosed out of a trophy then maybe it's time to sprinkle that magic powder on the engine.

OK, so you've done all this soul-searching, spent a hundred dollars on a lot of dials and plumbing, swept out the garage, torn your engine apart, measured and gauged the hell out of it, read every book and catalog on the subject, so let's go to work.

BETTER BREATHING

The simplest and most beneficial single thing that will yield more horsepower out of your power plant is to make it easier for air to flow into the engine. The first thought most people have on this subject is bigger carburetor, bigger ports, bigger valves. Let's blow this off right away. The most natural thing to do when you want more push is to turn the throttle wide open. If the engine is turning over slowly this means there will be an immediate drop in the velocity of the air passing through the carburetor. This drop means less gas and if the drop is severe enough—blah, no go. Putting a bigger carb on can only make such conditions worse. Now when you see something like a Triumph TR6 sporting one carb while its flashy brother Bonneville has two, you know more carburetion is the answer. Actually the TR6 carb is working more efficiently while the pair are only working half time. What holds the TR6 back at the top end is the two tight turns in the manifold. Some engines are intentionally equipped with undersize carburetors to account for the riders who are slow on the shift and quick on the throttle. This keeps down the complaints for the manufacturer and is a safety feature to prevent a stuck throttle from blowing the engine. The best rule for carburetor size is don't make it any bigger than the ports, and the best rule for ports is don't make them any bigger than the valve throat.

The reason for matching valve, port and carburetor size lies in the understanding of the mechanics of gas flow. Gasses have to obey the same

physical laws of motion as solids. Objects at rest tend to stay at rest, and objects in motion tend to remain in motion along a straight line and at the same speed. Putting an object at rest into motion or changing the speed or direction of an object in motion requires the application of force. The amount of force required to change the motion of an object is directly proportional to its mass and to the rate at which the motion is changed. The amount of motion an object has at any moment in time is called velocity, and the rate at which the velocity is changed is called acceleration.

Air is pretty light at .075 pounds per cubic foot, and it doesn't take much force to move it around if you're fanning yourself; but a 20 cubic-inch cylinder is gulping 40 cubic feet of air per minute at 7000 rpm and through a 30mm carburetor it means that air has to have an average velocity of 350 feet per second. The flow of air through the carburetor is not continuous either. The suction force of the piston can only be applied on the intake stroke so the time available for these gulps of air is only .0043 second. The average velocity of 350 fps is based on the average piston speed, but the piston starts out at TDC with a velocity of zero, accelerates to 1.64 times the average speed about half way down and then comes to a halt at BDC. This means that the air is trying to go from zero to 575 fps through the carburetor and get into the cylinder to fill it up in .0043 seconds. 20 cubic inches of air isn't much, but to kick it up to 390 mph in that short a time takes about three pounds of push, and at 3500 times a minute that amounts to about ½ horsepower.

If our 390 mph gulp of air were traveling in a long straight tube with perfectly smooth walls it would go a long way with the initial push. Trouble is, this isn't the case and there are three things that tend to slow that air down and require even more horsepower to get it into the cylinder. Two of these things follow the laws of motion: Change in velocity and change in direction. Any restriction in the port requires the air to increase in velocity and any increase in size causes the air to slow down. The bend in the port between the carburetor and the valve means a change in direction. All this speeding up, slowing down and bending around requires various forces to act on the air and that takes power. The third thing that requires power to move air is friction. Even in a straight tube with polished walls, the air next to the wall tends to stick to it and slow down, but the air in the middle keeps going at a greater speed. The result is that the air next to the wall swirls around in little eddy currents, and the stronger these eddies, the more they are felt throughout the entire stream of air. A high-velocity stream of air generates eddy currents throughout and is said to be in a state of turbulent flow. All of this turbulence in the air stream boils down to a continuous changing of velocity and direction of all the air particles, and that takes more power if the whole airstream is to keep moving at the same speed. Turbulent flow exists in any high-speed air stream, even in a smooth-wall tube, but if that tube has rough walls the turbulent condition increases radically and power requirements go up more.

In talking about moving air we've been referring to the forces required as though the air were a solid that we could measure forces against with some sort of gauge or scale. Of course air isn't something you can get a firm grip on so the forces have to be measured as pressure in terms of some unit of force exerted by the air against a surface of some unit area. The pressure units commonly used are pounds per square inch (psi).

In an unsupercharged engine, the maximum pressure available to move the air into the cylinder is 14.7 psi. This is the pressure that the atmosphere exerts on the surface of the earth. As you go up in altitude there is less air, therefore less pressure. When the piston begins to move down in the cylinder a void is created and the air pressure in the cylinder drops below 14.7 psi. This drop in pressure is what enables the atmospheric pressure outside the cylinder to push air in. When the piston is stationary, there is no movement of air and the pressure in the cylinder is the same as outside. It is the difference in pressure, or drop that causes the air to move. In any moving stream of air there is a pressure drop in the direction of flow. That is, the pressure downstream is always lower than upstream pressure. The faster the air is moving the greater the drop in a given distance.

1. Ways to go with pistons: From left to right are the stock 9.0:1 C. R., the 10.5:1 with cutaway skirt to compensate for added dome and the 12.5:1 with holes to remove further added weight.

2, 3 and 4. The before and after of porting. These Harley Sportster heads show it's not how much but what you do that counts. The valve guide boss isn't completely removed, just cut down and shaped to make it easier for the air to get around. The sharp transition into the valve throat is also blended into the port wall. The valve seats may look farther apart, but they've just been rounded off for smoother flow.

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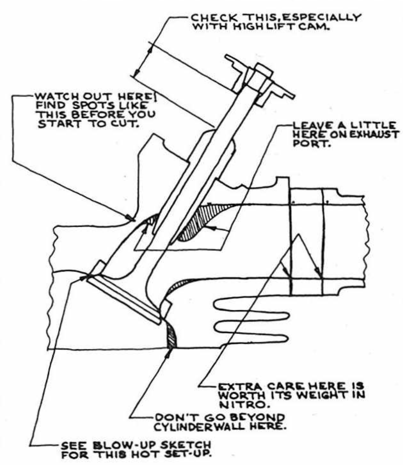
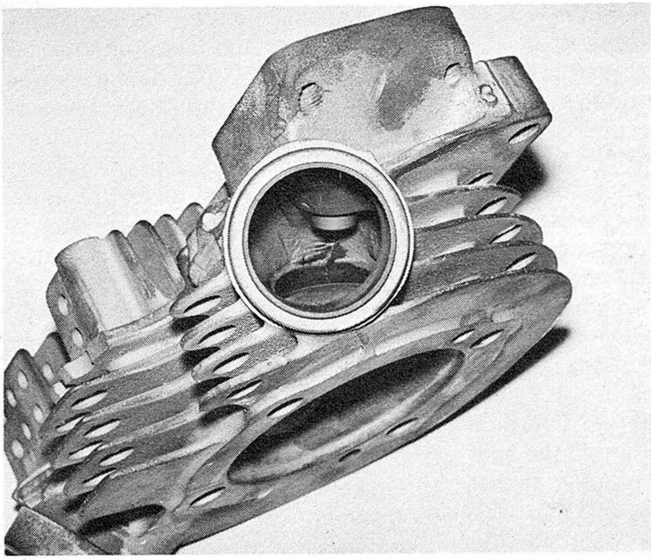
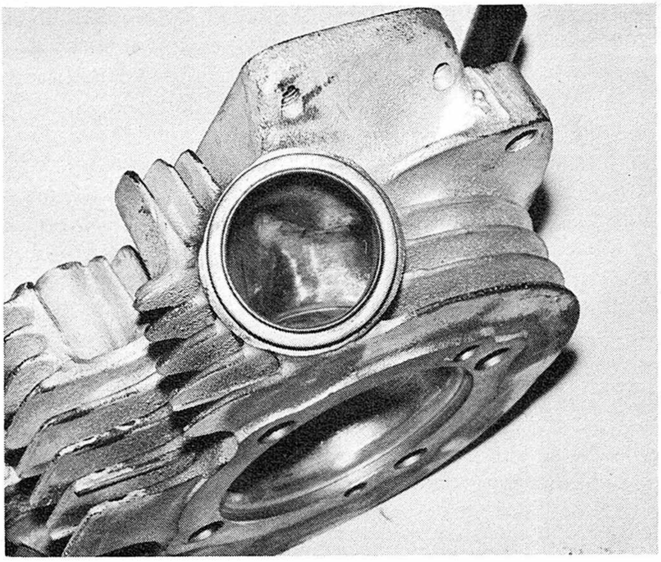
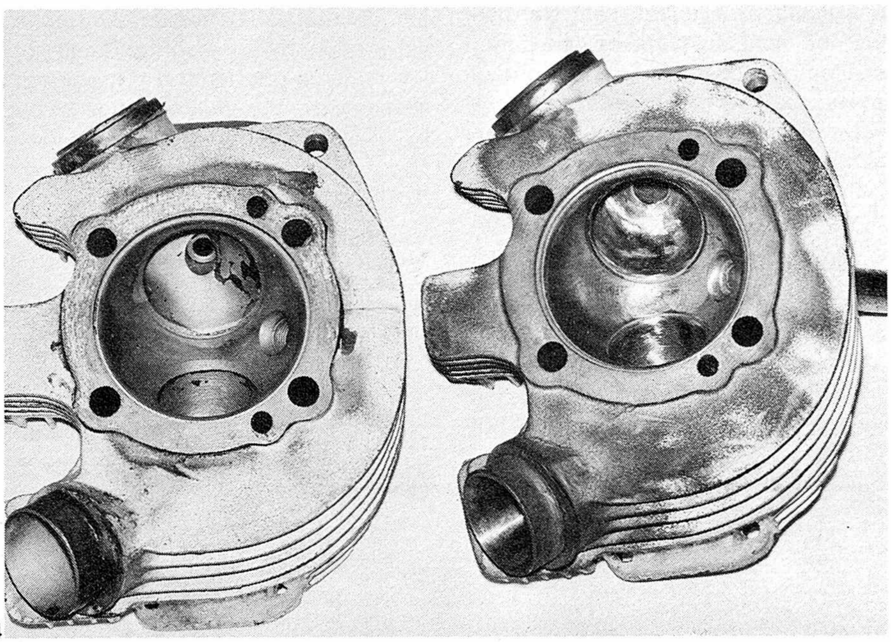


SKETCH #9

MAKE ROOM FOR THE AIR

2 

3 

4 

The faster the piston moves on the intake stroke, the greater the pressure drop will be, and the air will be accelerated at a greater rate. This is good? No, because the faster the piston moves, the rarer the air becomes in the cylinder and the less time there is for the incoming air to fill the void before the valve closes. This is where the cylinder is drawing in less air than it can actually hold and it's called low volumetric efficiency. Not only does low volumetric efficiency occur at high piston speeds, it also occurs when there are intake restrictions which cause pressure drop. This brings us to the conclusion that the greater the pressure drop, the lower the volumetric efficiency. Low volumetric efficiency results in a multiple power loss. High pressure drop requires more power to pump the air and less air means less fuel and lower compression pressure, therefore less thermal efficiency and less effective combustion pressure. This is where those little differences in intake configuration that increase volumetric efficiency can give such dramatic improvement in power output.

SPEED IT UP

There are a couple of basic operations which can do so much for so little. Care and patience are the prime ingredients here and the results can be really satisfying. Beginning at the carburetor flange, check the match of the carburetor with the insulator block and the block with the port. The slightest discontinuity at these joints will produce considerable unwanted turbulence. Here's where you're going to have to put out some more loot to do it yourself. A high-speed hand grinder is the speed mechanic's best friend. For about $30.00 you can buy an inexpensive, lightweight grinder complete with filing, milling, routing, grinding and sanding bits. Unless you're going into the business, a lightweight grinder is easier to handle for the beginner than the more expensive heavy-duty industrial type. By the way, see if you can scrounge up a junked head from a friendly dealer and do a little practice grinding and polishing on it before starting on the real thing.

When it comes to port size, the limit is the valve seat. Working from there, make any change in diameter as long and as gradual as possible, keeping in mind that it's the suddenness of change in velocity or direction that causes unwanted pressure drop. This brings us to the valve itself where the greatest change in flow takes place. The rapid velocity change of about six to one at this point is the big loser, but before you come up with any ideas about reducing that velocity change with bigger valves, let's finish the argument for leaving it alone. The tendency for something to stay in motion increases with the square of the velocity and is proportional to its mass. All of the air moving through the carburetor, intake duct and port is moving at the same speed, and once it accelerates to its top speed it wants to stay there. This is good. When the piston starts to slow down and come to a stop at the bottom of the stroke, the air keeps coming in. For that matter, it wants to keep coming in even after the piston has started to come back up for the compression stroke. The reason for closing the intake valve some time after BDC is to take advantage of this inertial property of the moving air to fill the

cylinder to capacity. The faster the air is coming in, the longer the valve can be held open, but we'll talk about this later. Just as the velocity improves the flow of air into the cylinder, it also brings about higher pressure losses so there is a point where the advantage of the inertial "ramming" is lost to pressure drop. Through theoretical calculations and extensive testing several different researchers have come up with the same answer: 350 feet per second for the average engine. A survey of 22 currently produced four-stroke bike engines shows that they have air velocities through the carburetor ranging from 300 to 350 fps at maximum power rpm. Now these are average engines. If you've really done a good job of reducing pressure losses in the port, the velocity can go as high as 450 fps before the speed advantage is lost. By now you should see the reasons for not jumping on the "make-it-bigger bandwagon" and instead, joining the "make-it-cleaner party", so let's come back to that valve seat.

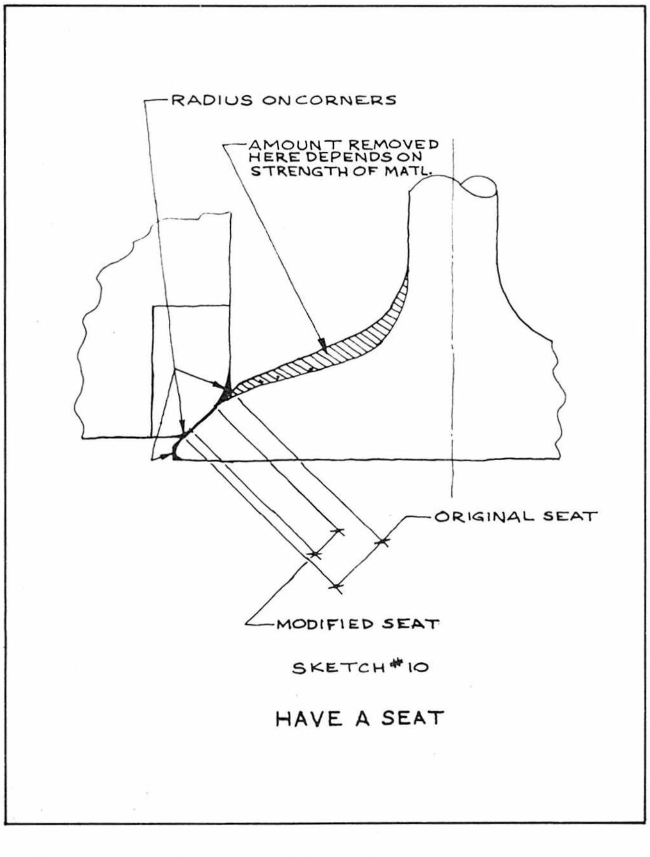
Drawing air into, or expelling it from, the end of a pipe should theoretically require only the energy necessary to accelerate the air up to speed. The air directly in front of the end of the pipe has only to travel in a straight line, but the air around the edges has to make a sharp turn to flow into the pipe and the air on the inside next to the wall has to make a sharp turn to pass out. All this takes more horsepower, so any help that will make it easier for the air to do its thing will mean less pressure drop. The sharp edges of a valve seat are good turbulence generators and rounding them off will aid considerably in improving volumetric efficiency. The problem with rounding off the valve and seat is that it reduces the width of the seating surface, which reduces its useful life. One nice thing about it though is that the seat in most engines was designed to last forever, besides the seat has to be a minimum size to be cast into the head, and that's more than big enough for an adequate seat. Narrowing the seat also makes for better sealing because it raises the contact pressure. This job is best left to a valve grinding specialist who has the stones already dressed and is familiar with this type of rework. Don't run down there to have the seats ground until you have the valves and guides ready to install. The guides will have to be pressed in and reamed to fit the valve stems, then they are used as a pilot for the seat grinder.

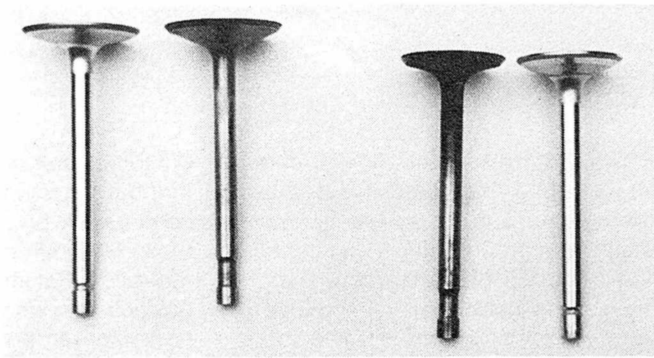
The width of the stock valve seat may be a lot more than necessary, but too narrow a seat will wear fairly quickly, so you should consider the practical limits here. For minimum pressure drop, the bigger the radius the better, but this means a narrower seat. A seat width of about .05-inch per inch of valve diameter is considered about minimum, and will require re-facing about every 50 to 100 hours of operation, depending on use. A little bit wider seat will extend valve life quite a lot—.075-inch per inch of diameter should be good for about 500 hours of moderate use. Rework of the valve itself can be a little tricky, so be sure to check this out carefully with your valve man. Removing material for weight reduction will be of great help at higher rpm and shaping of the underside of the valve head can improve air flow; not so much when full-open but at partial opening. The amount that can be removed from the valve depends a lot on the quality of the material and its size. The bigger in diameter, the thicker it has to be to resist bending. If your valves look

1. The valves on the ends are what C. R. Axtell replaces stock Triumph 650 valves with. Note the narrower seat surface, deep retainer groove.

2. Higher lift and longer duration of the cam requires lightening, polishing and peening of the rockers to relieve valve train loads.

3. The hard-face build up of the Honda four cam on the right shows the difference in duration and timing from a stock one.

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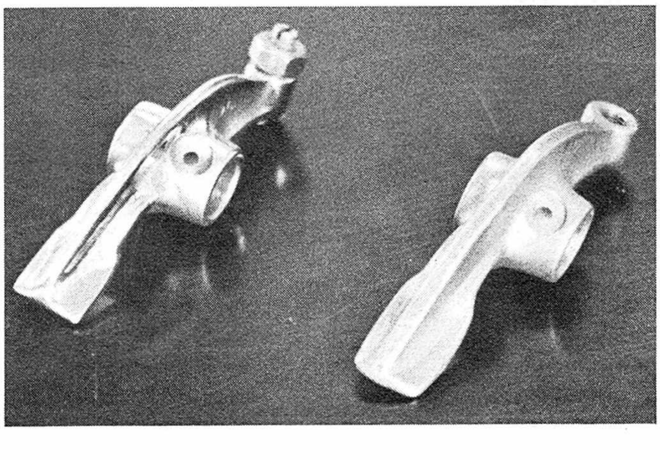
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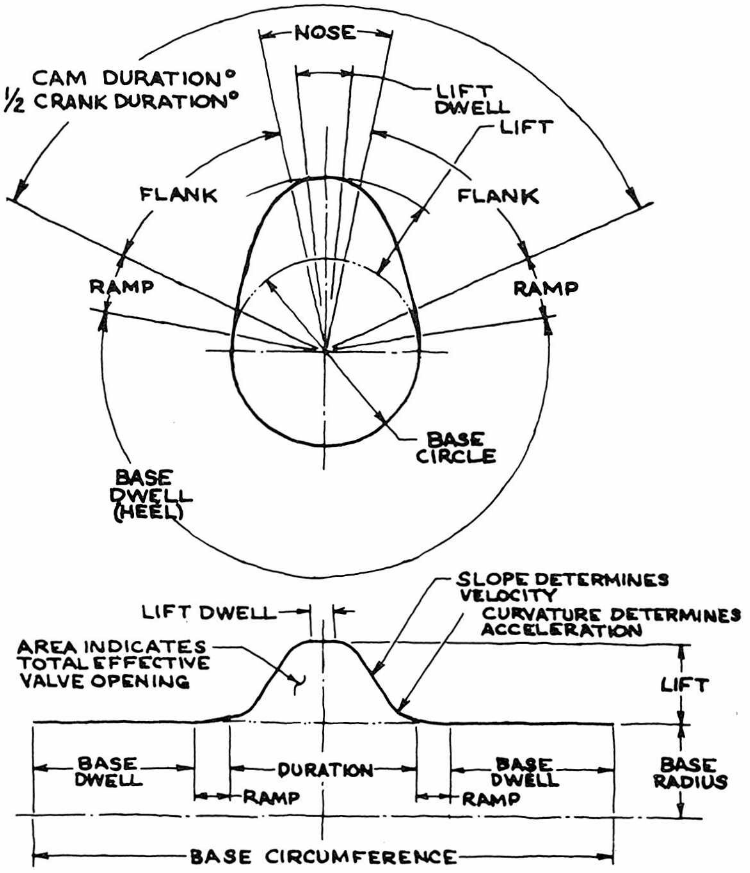
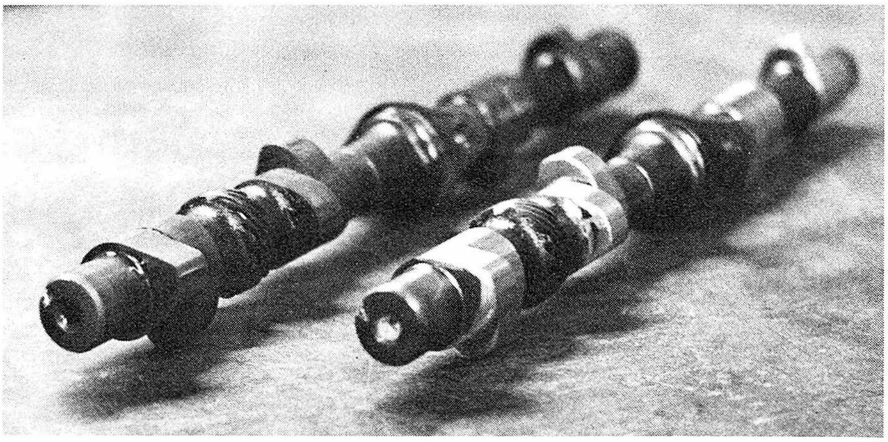


SKETCH #11

THE CAM STORY

3 

unusually thick it's because the manufacturer is very conservative or he's cutting material costs. More than likely it's a cost cut. Good replacement material can be found in most automotive valves, but of course it's going to cost you to have them machined to fit. It's well worth it though if you're after maximum performance and long valve life. By the way, the high rollers weld Stellite tips on the stems; they last much longer at high speeds. Once you've had the seats and valves worked over, the final touches are up to you to ensure perfect sealing. Those narrow seats are useless unless the valves have been lapped in to the nth degree. Don't hurry this job; it's worth the time.

The last part of head clean-up is in the combustion chamber itself. An important factor here is removal of any sharp edges or protrusions that might glow at high temperatures and cause pre-ignition. Don't forget that last thread in the spark plug hole. Any pocketing or shielding of the valve should be cut away, and the edge of the chamber adjacent to the cylinder bore should be matched up with the bore. Don't forget the head gasket either, it should line up flush with the bore all the way around. Up to this time we've been talking about reducing turbulence to cut down on pressure drop, but turbulence is what is needed in the combustion chamber to ensure rapid and complete burning of the fuel. In most spherical combustion chambers the domed piston is designed to approach the wall of the chamber very closely to give a "squish" to the charge and increase its turbulence. In some designs, the head actually hangs over the edge of the cylinder bore and a flat area on the piston head provides the squish. If your head has this type of overhang don't cut it off to match the bore! Just round off the edge where it intersects the chamber and let it do its job. The overall finish in the head should be super-smooth and here a high polish gives a little boost to thermal efficiency along with detering carbon deposits. The valves of course should be smoothed to the same degree as the port and head.

The exhaust port requires about the same treatment as the intake, but here a little conservatism is in order because of the much higher temperatures the valve sees. Valve seat width should be a bit wider than the intake for better cooling (seat contact is the exhaust valve's best cooling path), and a small amount of guide boss will help cooling there too. Exhaust valves are generally smaller than intakes, primarily to make more room for the intake and to reduce bending in the valve head. For this reason don't try to remove too much material from the exhaust to lighten it; it's already lighter than the intake. Saving pressure drop in the exhaust port reduces pumping losses a little, but compared to the length of the rest of the system, it's a pretty small percentage. Don't take that too lightly—a clean, smooth exhaust system can mean a couple of horsepower over one that's got a rough coating of carbon in it.

Now comes the tough part. If you have a single, skip this paragraph, but chances are you're working over a twin or even four cylinders, so bite your lip and get ready to sweat. Once you have completed the ports and combustion chamber for one cylinder,

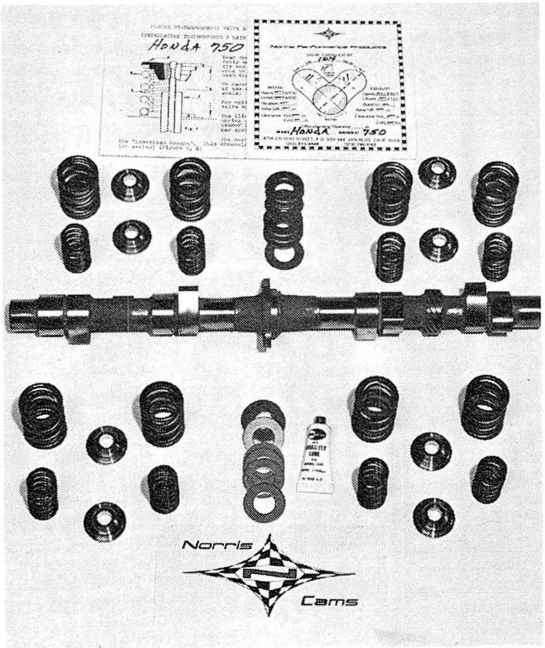
its time to do the old measuring routine again. This time it's very critical that you do a thorough and accurate job because you'll have to duplicate what you have done as closely as possible on the other cylinders. To estimate the magnitude of the task you'll be undertaking, let's quote a few man hours. A production-type port and polish job by a guy who's done it a hundred times using all the trick equipment takes about two hours per cylinder. A custom tuner doing a repeat of something he does with some regularity will spend about four hours on each cylinder. Starting from scratch, a pro will spend one or two days and sometimes longer developing the rework of the ports and head of one cylinder. Now this is a guy who does it for a living, has all kinds of facilities at his disposal and has done similar jobs many times before. How long do you think it should take you?

If you know what is meant by "visualization" then you should realize that working on the inside of something from the outside isn't easy when the outside has no correlation to the inside, and you're used to seeing it from the outside. If you were making up an exhaust pipe and had to bend it around to fit in close, you could see what you were doing quite easily. On the other hand, working on a port doesn't give you a chance to cut and try without some sort of termite or earthworm insight. Attacking a port with a grinder and without a definite plan of what to do is an invitation to the heli-arc welder and machinist, and that will really cost you. What you need to duplicate the work done on the first set of ports on all the others is the same thing you'll need to begin the job. Templates of the profiles of the various features of the port are the best way to bring the inside to the outside where you can really have a good look at it. Making templates before you begin will give you a clear picture of where you're at, and templates of the finished job will tell you what to do with the other ports . . . If you've never done this kind of work before you should plan on spending two or three days on the first one, and most of that time will be spent in measurement and study of the situation if you don't want to botch it. Lottsa luck!

THE CHOICE IS YOURS

Up to now we've talked mostly about making it easier for the air to pass into the cylinder without regard for the time when it's supposed to be there. As you have probably seen from our discussion so far, the timing of the events in the operation of an engine is as important to its performance as the configuration of the parts. Space just doesn't allow a complete dissertation on the subject of cams because the details are so numerous they could fill a book in themselves. What we'll do here is talk about some of the more important details affecting installation, and you'll have to rely pretty heavily on the information you can find out from the cam grinders. The important thing is that you are familiar with cam terminology, understand some of the problems in the design and manufacture of cams, and know your own engine and what you can expect from it. If you've done your homework the people you talk to will appreciate it and will be able to help you to better achieve your goals.

The most critical factors in valve action are the velocity and acceleration of the entire valve train. The governing factor is the natural frequency of oscillation of the train. This is dependent on the "rate" of the valve spring and the weight of all the moving parts. The stiffer the spring, the higher the frequency, and the heavier the parts, the lower the frequency. Spring rate is not just the load on the spring but the load per inch of deflection. The velocities and accelerations indicated by the diagram are only relative; the actual values are in direct proportion to engine rpm. Now, the object in designing a cam is to obtain the maximum effective valve opening for any given duration. This is done by increasing lift or the lift dwell in order to increase the area under the included diagram. It can be seen from the diagram that any increase in these values requires an increase in velocity and, any increase in velocity requires greater acceleration if there is no additional time. The upshot of all this is that if the valve train reaches accelerations or velocities approaching those associated with its natural frequency, it will tend to keep right on moving after the cam has reached full lift. The valve train will stop when the spring bottoms out and then it will return upon the cam with a resounding crash



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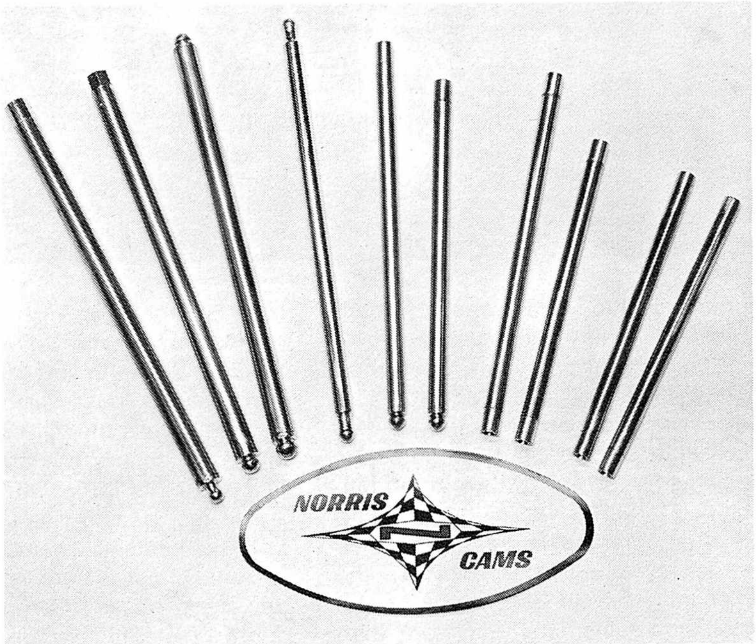

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1. Norris is offering a billet cam for the Honda 750 along with a kit of springs and lightweight retainers. This is the way to buy a cam; everything is properly matched.

2. Weight and strength of pushrods are conflicting requirements well met in this assortment.

3. The variety of shims shown at the bottom are for obtaining the proper 'pack' length of the valve springs to insure uniform seating.

which is heard as valve float or bounce. None of the parts last very long under this kind of pounding. Excessive acceleration without reaching critical velocity will result rapid wear of the cam face and lifter.

For a given duration, a cam can only do so much. The cam designer is faced with numerous problems. He can juggle the accelerations at top and bottom, sacrifice some lift dwell and make the cam out of super-hard material to give you a little more effective opening, but his biggest problem is you. How heavy are all your valve train parts, what kind of spring will you use, and how fast are you going to try to run it? At these things he can only make a guess based on his experience and pass these guesses along to you as recommendations, and you better listen!

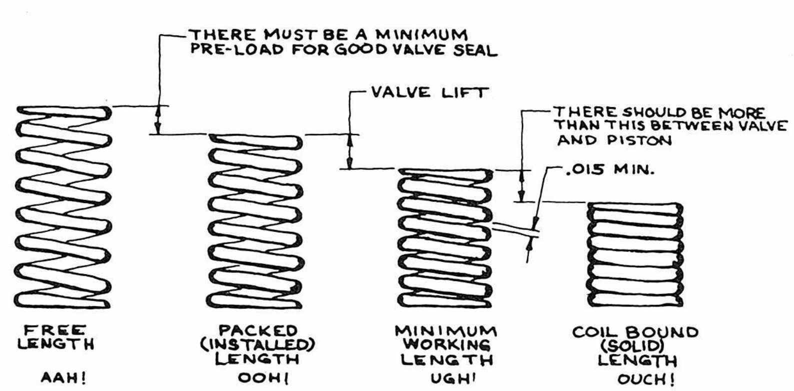
Of course, your cam grinder can give you more valve opening by extending the duration, but this now takes you into the realm of timing and overlap. Optimum valve timing is based on the relation of piston velocity to the average velocities, of the intake air and exhaust gasses. The valves may be closed after dead center and the piston is moving in the opposite direction up to the point where the piston velocity reaches the gas velocity. This point is approximately 30 degrees after TDC on the down stroke and 50 degrees after BDC on the up stroke. The same holds true for the opening of the valve to take advantage of the velocities generated on the previous cycle. You'll find these figures of 30 and 50 degrees pretty close to the average timing for engines operating up to the 6000 rpm range. Slower-speed engines are generally more conservatively timed closer to dead center because of lower gas inertias, and higher speeds permit longer durations but with a sacrifice in low-speed output. Overlap is the period when the exhaust and intake are open at the same time and advantage can be gained from the outflowing exhaust to help start the intake. The amount of useful overlap is also dependent on engine speed, and this is another area where the cam designer can trade off overlap and timing to achieve variations in performance. Each cam grinder has his pet combinations based on the way the particular cam was developed. What you'll have to do is shop the various cam sources and see which one had the same uses in mind as you.

SPRINGS 'N THINGS

Once you've selected the cam, look into what the grinder has to offer by way of springs, lifters, pushrods, etc. Buying from the same source will usually give you the best combination. When it comes to installation, listen to the cam grinder very closely. His recommended spring rates and packed lengths are based on what his cam will handle. Most important is lubrication of the cam for the first few minutes of operation. Special assembly lubes should be applied lavishly to the lobes and lifters and all other valve train mating surfaces in order to provide that important break in of the highly loaded rubbing surfaces.

PISTONS

The last major item to be selected in your hot combination is the piston. The primary factor of concern here is *compression ratio.* Naturally, a higher compression will give you better thermal efficiency but premium



SKETCH #12

A DAY IN THE LIFE OF A VALVE SPRING

fuel and cool running temperatures are a must if you go the limit. If you have a considerably later intake closing than stock, you will be able to go quite a bit higher in CR because of lower compression pressure at all but the highest speeds. A good yardstick for judging compression ratio is the cranking pressure. Anything below 150 psi just isn't with it and pressures above 250 psi are in the realm of the fuelers. Table 1 lists the approximate relationship of nominal compression ratio and valve timing so that you may have some guide in selecting the ratio to suit your purposes. Checking that dome clearance with the valve lift is of course the most important installation procedure.

FINISHING TOUCHES

Balancing, lighening, polishing and peening of various critical parts is required in direct proportion to engine speed and expected life. About the best you can learn along these lines is find out what the hot shoes are replacing most often in your type engine.

Now that it's all buttoned up and back in the frame you'll want to tune on the exhaust and intake systems to get that magical added punch from the acoustical pulsing of the pipes. About the only place you can use this witchcraft is at the drags or on the salt flats, 'cause anything but stock mufflers on the street these days is a no-no and riding the dirt without an air cleaner is sheer insanity. Here are a couple of simple formulas for a first cut. L = length in inches measured from the valve head to the end of the pipe or air horn, N = the rpm where power peak is desired.

For intakes:

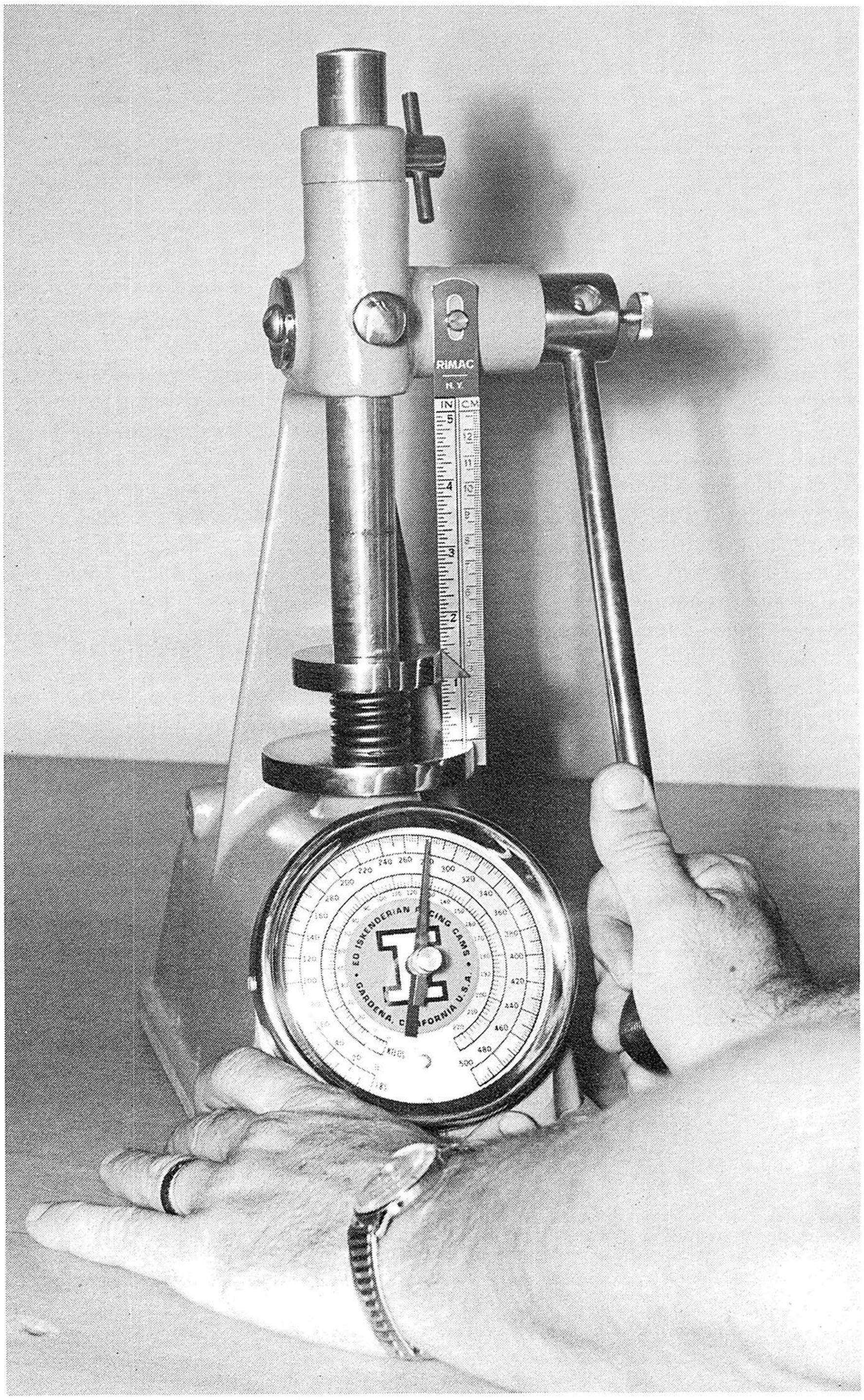
$$L = 88000 \div N$$

For exhaust:

$$L = 204{,}000 \div N$$

These are close approximations but individual bikes and riders will require some variation. Generally, extreme duration cams need a little bit longer than calculated pipe.

Carburetion, ignition and general tune-up are covered in detail in other chapters, so browse around this book and learn all you can. As far as carburetors go, there is no mystery about them. A *carburetor* cannot, repeat *cannot,* give you more power or gas mileage. The amount of air taken in by the engine is the sole measure of the power it can yield. Gasoline is merely a heat source, and the amount that the carburetor meters to the air passing through can only be that which will properly burn in the engine. There is a "chemically correct" mixture, an "economy" mixture only slightly leaner, and a "power" mixture only slightly richer. Anything beyond these limits will either not burn at all or will burn with such intense heat as to melt your piston or burn the valves. The basic principle of the carburetor is to furnish the right amount of fuel for the amount of air passing through. Some do a better job than others over a wider range of conditions but the differences lie in the engines to which they're fixed because of differences in operating temperatures, compres-



1

1. This is the easiest and most accurate way of checking valve spring characteristics. Springs should be checked after they have been used; they can loose their 'sap'.

2 and 3. Care is the most important ingredient in the recipe for power. Measurements like this should be made both before and after changes are made and carefully recorded for future reference. Problems are more easily traced if all the facts are at hand.

APPROXIMATE COMPRESSION PRESSURE, PSI
Slow cranking, wide open throttle

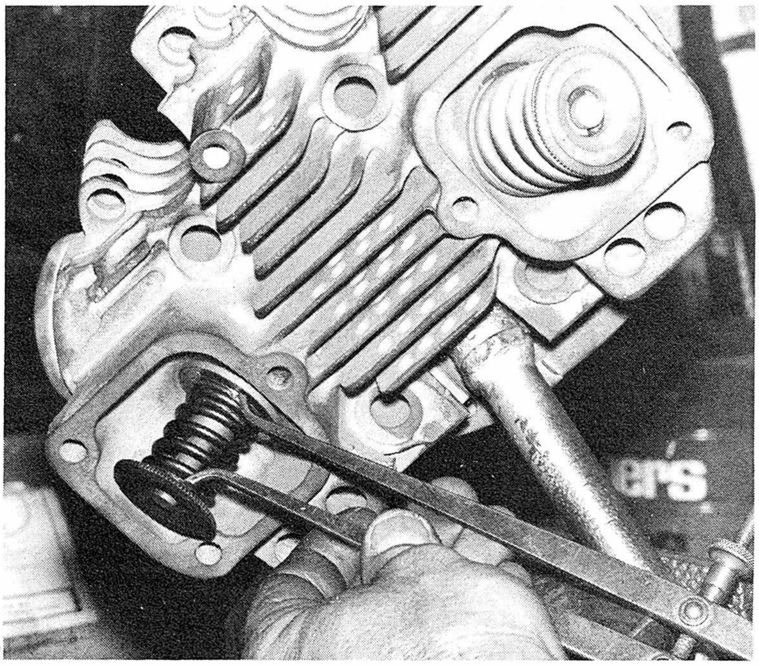
INTAKE VALVE CLOSING TIME, degrees after bottom center	NOMINAL COMPRESSION RATIO									
	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5
45°	191	209	225	243	260	279	298	316	355	354
50°	184	200	216	232	250	268	285	303	322	341
55°	175	191	206	223	240	256	273	290	307	324
60°	168	182	197	213	228	244	260	276	294	312
65°	160	173	188	203	218	234	248	265	279	294
70°	150	163	176	190	204	218	234	247	260	275
75°	140	151	165	178	190	204	216	231	244	258
80°	129	141	153	165	176	190	201	213	226	238
85°	121	131	141	153	163	175	187	197	209	220
90°	110	121	129	140	150	160	171	182	193	204

sion ratios, turbulence, etc. If you're still using the stock carburetor, start with the main jet a couple of sizes larger and concentrate on mid-range tuning. This is where the biggest change will take place because of cam changes. If you use a different carb find out the main jet size for the most widely used stock application and start from a couple of sizes larger.

Ignition timing is just that: a matter of timing. It all depends on the speed of combustion. The idea is to have about 5/9 of the combustion to take place before TDC to yield maximum pressure. Believe it or not, the stock timing does a pretty good job at this. A higher compression ratio might call for slightly retarded timing, but you'll probably want to speed it up some so start with stock timing and nudge it up about two degrees at a time. You'll know if it is too far advanced if it starts to overheat after some hard running.

About the only other thing to mention is gearing. By now you should be pretty firm in your intentions for the application of that added power so your main concern is to put it to the wheel for greatest advantage. All out maximum speed attempts require matching of the peak power rpm to the top speed of the bike. This usually takes pretty high (low numeric ratio) gearing which is totally unsuitable for street riding and even less so for racing. Street gearing should be high enough to keep engine speed at a respectable level for highway cruising, yet low enough to give good acceleration in traffic. For racing of almost all forms, acceleration is the big advantage so gearing must be such to deliver maximum power in the middle speed ranges. Cross-country racing motocross, or trail riding demand the widest range of power application and this is achieved through a gearbox with a good spread, but all can be lost if it isn't there on a bad hill, so low gearing is the order of the day. If you've been tuning on your street racer for a little more punch in the 60 to 70 mph range and now it gives you even more than you need, you can probably use another tooth on the counter sprocket. If you're going to try it at the drag strip you'll probably want a counter sprocket one tooth smaller. If your trail bike is bogging down in fourth gear and the engine is topping out in third, then one less tooth will let it wind out for full power delivery in fourth and give you better pull in third.

Whell, there it is, but not the whole story. There just isn't the room to tell it all here and even then there are some things that can't be told; they have to be learned. Again, the importance of knowing the details of your engine can't be stressed enough, and don't be too shy to ask. There are a lot of "neat tricks" that can only be found out by being 'in' with those who have learned the hard way. Best of luck. If you see me out there it'll be easy to 'shut the gate' on me, 'I'm strictly a "stocker"



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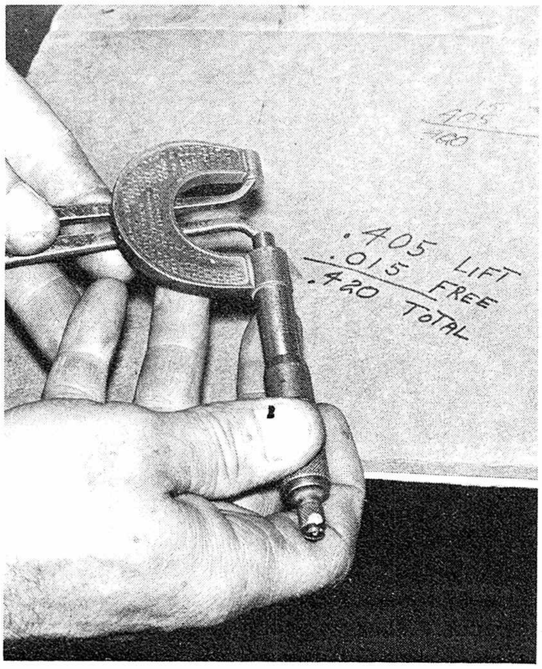


3

SHOP MATH

Don't let the title scare you, it's just a condensed way of saying specifications, charts, tables and formulas

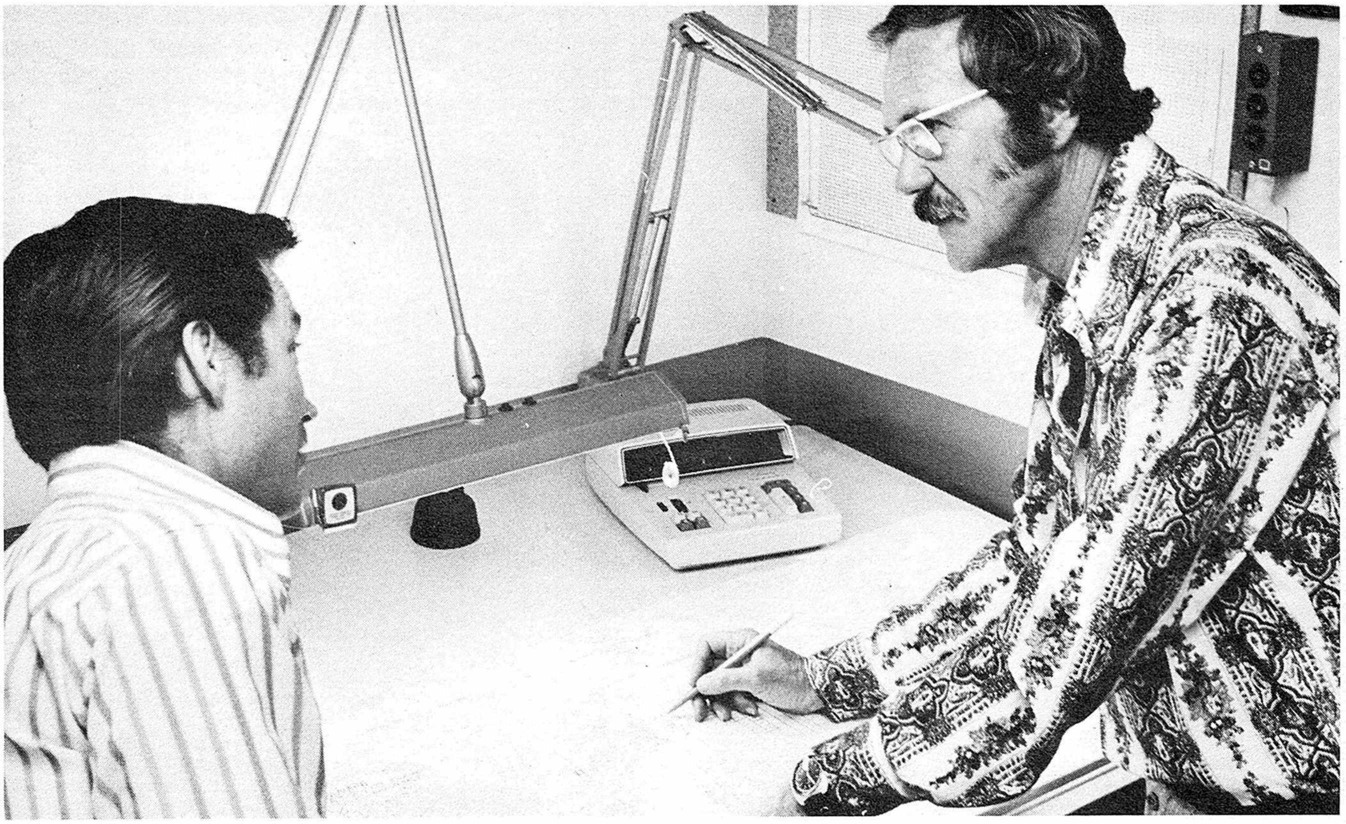
BY JOHN T. JO

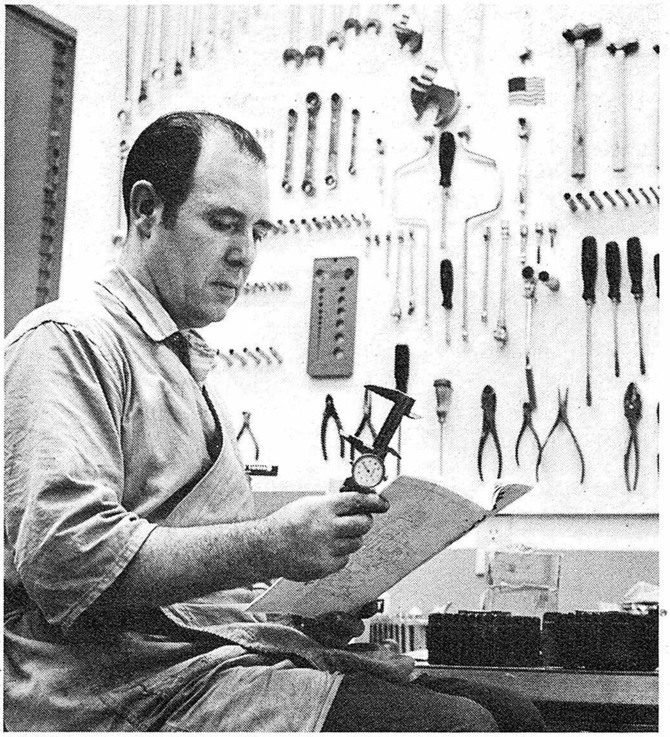
What does a prospective buyer do before he takes the dollar plunge and invests in what he thinks is the bike best suited for him? He collects dealer brochures and digests road tests that appear in the top motorcycle magazines to see which bikes are best, according to specifications. Fortunately, U.S. buyers have a world-wide array of different motorcycles to choose from. Most of the two-wheelers sold here are of foreign manufacture. Since Stateside riders are raised on the U.S. Standard measurement system, which is not, unfortunately, in accord with the European or Far East manufacturing companies who use metric values, a potential customer may have to CONVERT the metric values given by the factories to U.S. Standard inches, cubic inches, etc., to compare facts at his familiar measurement.

After an enthusiast purchases his new two-wheeler and puts a year or so on it, he may decide to start doing his own tune-ups, or make a couple of changes for higher performance or better handling. This is when a set of "conversion tables" may come in handy. For example, what if the point gap tolerance is given in millimeters and the only feeler gauge the weekend mechanic owns is of the inch variety? A simple conversion from metric to inch dimension will save a trip to the local tool store and an added expense. To aid the home tuner, this chapter includes Metric to American and American to Metric conversion tables. These tables require multiplication only and not any tedious long division. To convert, simply multiply your known dimension by the factor given to obtain the desired result. Along with the conversion tables, there is inserted a quick-conversion page of decimal-inch equivalents to millimeters.

Also included in this chapter is a specification page of letter and number drill sizes with their decimal equivalents. Fractions of 8th's, 16th's, 32nd's and 64th's and their decimal equivalents are boxed on the page too. What if the how-to manual says to drill a letter K or L, or 15 or 17 sized hole? What drill bit is closest to 19/64 of an inch? All these questions are answered in the easy to read, drill bit information boxes. Rounding out the specification section are the bolt torque charts. There are one each for U.S. Standard, Metric and Whitworth Standard. Bolt torque figures in all three charts should be used as a general tightening guideline; we recommend consulting an appropriate, official factory repair manual for specific bolt torques.

Beside conversions and specifications, formulas are used quite frequently in advanced and mechanical work. We'll cover the formulas most used in repair and maintenance. Remember! When substituting numerical values in formulas, work with complete Metric or U.S. Standard figures; don't intermix. After the answer is derived, it may then be converted to the desired form, Metric or U.S.





METRIC TO AMERICAN CONVERSION TABLE

MULTIPLY	BY	TO OBTAIN
(LINEAR)		
Millimeters (mm)	.03937	Inches
Millimeters (mm)	.00328	Feet
Centimeters (cm)	.3937	Inches
Centimeters (cm)	.0328	Feet
(DISTANCE)		
Meters (m)	39.37	Inches
Meters (m)	3.28	Feet
Kilometers (km)	3281	Feet
Kilometers (km)	.6214	Miles
(AREA)		
Square Centimeters (cm^2)	.155	Square Inches
Square Centimeters (cm^2)	.001076	Square Feet
Square Meters (m^2)	10.76	Square Feet
(VOLUME)		
Cubic Centimeters (cc)	.06102	Cubic Inches
Liters (l)	61.02	Cubic Inches
(LIQUID CAPACITY)		
Liters (l)	2.113	Pints
Liters (l)	1.057	Quarts
Liters (l)	.2642	Gallons
Cubic Centimeters (cc)	.0338	Fluid Ounces
(WEIGHT)		
Grams (gm)	.03527	Ounces
Kilograms (kg)	2.205	Pounds
(OTHER)		
Kilogram-Meters (kg-m)	7.233	Foot-Pounds (Ft.-Lbs.)
Kilometers/Liters (km/l)	2.352	Miles/Gallon (mpg)
Metric Horsepower (ps)	1.014	Brake Horsepower (bhp)

AMERICAN TO METRIC CONVERSION TABLE

MULTIPLY	BY	TO OBTAIN
(LINEAR)		
Inches (in.)	25.4	Millimeters
Inches (in.)	2.54	Centimeters
Feet (ft.)	304.8	Millimeters
Feet (ft.)	30.48	Centimeters
(DISTANCE)		
Inches (in.)	.0254	Meters
Feet (ft.)	.3048	Meters
Miles (mi.)	1.609	Kilometers
(AREA)		
Square Inches (in^2)	6.452	Square Centimeters
Square Feet (sq. ft.)	929	Square Centimeters
(VOLUME)		
Cubic Inches (cu. in.)	16.39	Cubic Centimeters
Cubic Inches (cu. in.)	.01639	Liters
(LIQUID CAPACITY)		
Pints (pt.)	.4732	Liters
Quarts (qt.)	.9463	Liters
Gallons (gal.)	3.785	Liters
Fluid Ounces (fl. oz.)	29.58	Cubic Centimeters
(WEIGHT)		
Ounces (oz.)	28.35	Grams
Pounds (lb.)	.4536	Kilograms
(OTHER)		
Foot-Pounds (Ft.-Lbs.)	.1383	Kilogram-Meters (kg-m)
Miles/Gallon (mpg)	.4252	Kilometers/Liter (km/l)
Brake Horsepower (bhp)	.9862	Metric Horsepower (ps)

SHOP MATH

U.S. STANDARD

GRADE OF BOLT		SAE 1 & 2	SAE 5	SAE 6	SAE 8		
MIN. TENSILE STRENGTH		64,000 P.S.I.	105,000 P.S.I.	133,000 P.S.I.	150,000 P.S.I.		
GRADE MARKINGS ON HEAD						SOCKET OR WRENCH SIZE	
U.S. STANDARD		TORQUE (IN FOOT POUNDS)				U.S. REGULAR	
BOLT DIA.	U.S. DEC. EQUIV.					BOLT HEAD	NUT
1/4	.250	5	7	10	10.5	3/8	7/16
5/16	.3125	9	14	19	22	1/2	9/16
3/8	.375	15	25	34	37	9/16	5/8
7/16	.4375	24	40	55	60	5/8	3/4
1/2	.500	37	60	85	92	3/4	13/16
9/16	.5625	53	88	120	132	7/8	7/8
5/8	.625	74	120	167	180	15/16	1.
3/4	.750	120	200	280	296	1-1/8	1-1/8
7/8	.875	190	302	440	473	1-5/16	1-5/16
1.	1.000	282	466	660	714	1-1/2	1-1/2

MULTIPLY READINGS BY 12 FOR INCH POUND VALUES

METRIC STANDARD

GRADE OF BOLT		5D	8G	10K	12K		
MIN. TENSILE STRENGTH		71,160 P.S.I.	113,800 P.S.I.	142,200 P.S.I.	170,679 P.S.I.		
GRADE MARKINGS ON HEAD		5D	8G	10K	12K	SOCKET OR WRENCH SIZE	
METRIC		TORQUE (IN FOOT POUNDS)				METRIC	
BOLT DIA.	U.S. DEC. EQUIV.					BOLT HEAD	NUT
6mm	.2362	5	6	8	10	10mm	10mm
8mm	.3150	10	16	22	27	14mm	14mm
10mm	.3937	19	31	40	49	17mm	17mm
12mm	.4720	34	54	70	86	19mm	19mm
14mm	.5512	55	89	117	137	22mm	22mm
16mm	.6299	83	132	175	208	24mm	24mm
18mm	.709	111	182	236	283	27mm	27mm
22mm	.8661	182	284	394	464	32mm	32mm
24mm	.945	261	419	570	689	36mm	36mm

WHITWORTH STANDARD

GRADE OF BOLT		A & B	S	T	V		
MIN. TENSILE STRENGTH		62,720 P.S.I.	112,000 P.S.I.	123,200 P.S.I.	145,600 P.S.I.		
GRADE MARKINGS ON HEAD			S	T	V	SOCKET OR WRENCH SIZE	
WHITWORTH		TORQUE (IN FOOT POUNDS)				WHITWORTH	
BOLT DIA.	U.S. DEC. EQUIV.					BOLT HEAD	NUT
1/4	.250	5	7	9	10	*1/4	*1/4
5/16	.3125	9	15	18	21	*5/16	*5/16
3/8	.375	15	27	31	36	*3/8	*3/8
7/16	.4375	24	43	51	58	*7/16	*7/16
1/2	.500	36	64	79	89	*1/2	*1/2
9/16	.5625	52	94	111	128	*9/16	*9/16
5/8	.625	73	128	155	175	*5/8	*5/8
3/4	.750	118	213	259	287	*3/4	*3/4
7/8	.875	186	322	407	459	*7/8	*7/8
1.	1.000	276	497	611	693	*1.	*1.

*Dimensions given on handles of U.S. wrenches refer to actual size of bolt head or nut. Dimension given on Whitworth wrenches refer to the shank or body diameter of the bolt, NOT THE BOLT HEAD OR NUT SIZE.

FORMULAS

ENGINE FORMULAS

PISTON DISPLACEMENT=bore diameter² (squared) x .7854 x stroke length.

Example: An engine has a bore diameter of 70mm and a stroke length of 64mm; find piston displacement.

piston displacement=70mm x 70mm x .7854 x 64mm

piston displacement=246301 cubic millimeters; divide answer by 1000 to get cubic centimeters. 246301 divided by 1000 =246.301 cubic centimeters.

ENGINE DISPLACEMENT=piston displacement x number of cylinders.

Example: An engine has a piston displacement of 246.3 cubic centimeters and two cylinders; find engine displacement.

engine displacement=246.3cc x 2 cylinders

engine displacement=492.6 cubic centimeters

$$\textbf{COMPRESSION RATIO}=\frac{\text{piston displacement + combustion chamber vol.}}{\text{combustion chamber volume}}$$

Example: Piston displacement is 246cc and the combustion chamber volume is 36cc; what is the compression ratio?

$$\text{compression ratio}=\frac{246\text{cc} + 36\text{cc}}{36\text{cc}}$$

compression ratio=7.833 (to one)

(See chapter on "Four-Stroke Hop-Up" under "actual volume" for specific compression ratio details)

$$\textbf{PISTON SPEED}=\frac{\text{2 x stroke length (in inches) x rpm}}{12}$$

Example: An engine has a stroke length of 2.31 inches; what's the piston speed at 7500 rpm?

$$\text{piston speed}=\frac{\text{2 x 2.31 inches x 7500 rpm}}{12}$$

piston speed=2887.5 feet per minute

$$\textbf{HORSEPOWER}=\frac{\text{torque x rpm}}{5252}$$

Example: An engine produces 40 foot-pounds of torque at 6500 rpm; what's the horsepower?

$$\text{horsepower}=\frac{\text{40 foot-pounds x 6500 rpm}}{5252}$$

horsepower=49.5

$$\textbf{TORQUE}=\frac{\text{horsepower x 5252}}{\text{rpm}}$$

Example: An engine churns out 37 horsepower at 8700 rpm; how much torque is generated?

$$\text{torque}=\frac{\text{37 hp x 5252}}{\text{8700 rpm}}$$

torque=22.3 foot-pounds

$$\textbf{PRIMARY REDUCTION RATIO}=\frac{\text{no. of teeth on clutch driven sprocket or gear}}{\text{no. of teeth on engine drive sprocket or gear}}$$

Example: Find primary reduction ratio if the machine has a 27 tooth engine sprocket and a 65 tooth clutch sprocket.

$$\text{primary reduction ratio}=\frac{65}{27}$$

primary reduction ratio=2.41 (to one)

This means there are 2.41 engine revolutions to each complete turn of the clutch.

$$\textbf{FINAL REDUCTION RATIO}=\frac{\text{no. of teeth on rear wheel sprocket}}{\text{no. of teeth on gearbox output sprocket}}$$

Example: There are 15 teeth on the gearbox output sprocket and 45 teeth on the rear wheel sprocket; what is the final reduction ratio?

$$\text{final reduction ratio}=\frac{45}{15}$$

final reduction ratio=3.0 (to one)

This means there are 3.0 gearbox output shaft revolutions to each complete turn of the rear wheel.

FIXED DRIVE RATIO=primary reduction ratio x final reduction ratio.

Example: Primary reduction ratio is 2.41 and the final reduction ratio is 3.0; calculate the fixed drive ratio.

fixed drive ratio=2.41 x 3.

fixed drive ratio=7.23 (to one)

$$\textbf{INTERNAL GEAR RATIO} = \frac{\text{no. of teeth on specific driven gear}}{\text{no. of teeth on specific drive gear}}$$

Example: Find 5th gear internal ratio if 5th drive gear has 26 teeth and 5th driven gear has 21.

$$\text{5th internal gear ratio} = \frac{21}{26}$$

5th internal gear ratio = .81 (to one)

(Note: In some transmissions, particularly British, two pairs of gears are used per each internal gear ratio. When this is the case, use the following internal gear ratio formula.)

$$\textbf{INTERNAL GEAR RATIO} = \frac{\text{no. of teeth on specific layshaft gear}}{\text{no. of teeth on specific mainshaft gear}} \; \frac{\text{no. of teeth on mainshaft top gear}}{\text{no. of teeth on layshaft top gear}}$$

Example: Layshaft 3rd gear has 22 teeth, mainshaft 3rd gear has 26 teeth, mainshaft top gear has 23 teeth and layshaft top gear has 17 teeth; find 3rd internal gear ratio.

$$\text{3rd internal gear ratio} = \frac{22}{26} \times \frac{23}{17}$$

3rd internal gear ratio = 1.144 (to one)

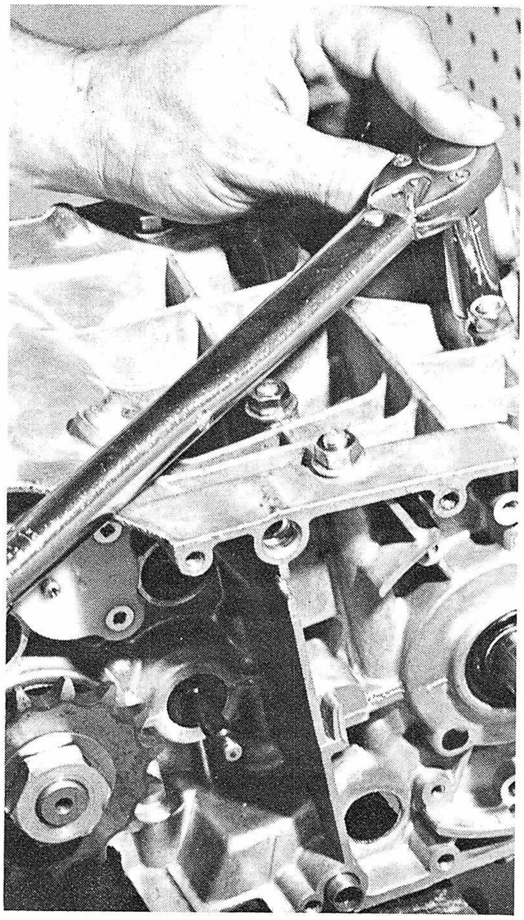
These give you the number of drive gear revolutions (clutch revolutions if mounted on transmission) for each turn of the output shaft.

OVERALL DRIVE RATIO = fixed drive ratio x specific internal gear ratio.

Example: A motorcycle has a fixed drive ratio of 7.23 and internal gearbox ratios as follows:

Internal Ratio	**X**	**Fixed Ratio**	**=**	**Overall Drive Ratio**
Low 2.06		7.23		14.89
2nd 1.42		7.23		10.26
3rd 1.14		7.23		8.24
4th 0.96		7.23		6.94
Top 0.84		7.23		6.07

This gives you the number of engine revolutions for each turn of the rear wheel.



The following four formulas are used to compute motorcycle speed in MPH, engine speed in RPM, effective rear wheel radius in INCHES and overall drive ratio REQUIRED to attain the related velocity. These formulas are interrelated; where three factors are known, besides the 168 constant, the fourth may be determined mathematically. A word about accurately measuring effective rear wheel radius is due here; measure the radius distance in inches from the road surface-tire contact point, perpendicularly to the center of the rear axle with the tires properly inflated and the rider seated.

The four formulas are: $\text{MPH} = \frac{\text{rpm x effective rear wheel radius}}{\text{overall drive ratio x 168}}$

$$\text{RPM} = \frac{\text{mph x overall drive ratio x 168}}{\text{effective rear wheel radius}}$$

$$\text{OVERALL DRIVE RATIO} = \frac{\text{rpm x effective rear wheel radius}}{\text{mph x 168}}$$

$$\text{EFFECTIVE REAR WHEEL RADIUS} = \frac{\text{mph x overall drive ratio x 168}}{\text{rpm}}$$

Example: A motorcycle has a speed of 96.7 mph at 5000 engine rpm; the overall drive ratio (in third gear) is 4.00 to 1 and the rear wheel tire radius is 13 inches. These numerical values setup to solve for the ( ) unknown would look like this:

$$\text{(96.7) MPH} = \frac{\text{5000 rpm x 13-inch radius}}{\text{4.0 x 168}}$$

$$\text{(5000) RPM} = \frac{\text{96.7 mph x 4.0 x 168}}{\text{13-inch radius}}$$

$$\text{(4.0) OVERALL DRIVE RATIO} = \frac{\text{5000 rpm x 13-inch radius}}{\text{96.7 mph x 168}}$$

$$\text{(13-INCH) EFFECTIVE REAR WHEEL RADIUS} = \frac{\text{96.7 mph x 4.0 x 168}}{\text{5000 rpm}}$$

Decimal Equivalents
of 8ths, 16ths, 32nds, 64ths

8ths	32nds	64ths	64ths
1/8 = .125	1/32 = .03125	1/64 = .015625	33/64 = .515625
1/4 = .250	3/32 = .09375	3/64 = .046875	35/64 = .546875
3/8 = .375	5/32 = .15625	5/64 = .078125	37/64 = .578125
1/2 = .500	7/32 = .21875	7/64 = .109375	39/64 = .609375
5/8 = .625	9/32 = .28125	9/64 = .140625	41/64 = .640625
3/4 = .750	11/32 = .34375	11/64 = .171875	43/64 = .671875
7/8 = .875	13/32 = .40625	13/64 = .203125	45/64 = .703125
16ths	15/32 = .46875	15/64 = .234370	47/64 = .734375
1/16 = .0625	17/32 = .53125	17/64 = .265625	49/64 = .765625
3/16 = .1875	19/32 = .59375	19/64 = .296875	51/64 = .796875
5/16 = .3125	21/32 = .65625	21/64 = .328125	53/64 = .828125
7/16 = .4375	23/32 = .71875	23/64 = .359375	55/64 = .859375
9/16 = .5625	25/32 = .78125	25/64 = .390625	57/64 = .890625
11/16 = .6875	27/32 = .84375	27/64 = .421875	59/64 = .921875
13/16 = .8125	29/32 = .90625	29/64 = .453125	61/64 = .953125
15/16 = .9375	31/32 = .96875	31/64 = .484375	63/64 = .984375

Letter Size Drills

Letter	Size of Drill in Inches
A	.234
B	.238
C	.242
D	.246
E	.250
F	.257
G	.261
H	.266
I	.272
J	.277
K	.281
L	.290
M	.295
N	.302
O	.316
P	.323
Q	.332
R	.339
S	.348
T	.358
U	.368
V	.377
W	.386
X	.397
Y	.404
Z	.413

Number Size Drills

No.	Size of Drill in Inches	No.	Size of Drill in Inches	No.	Size of Drill in Inches	No.	Size of Drill in Inches
1	.2280	21	.1590	41	.0960	61	.0390
2	.2210	22	.1570	42	.0935	62	.0380
3	.2130	23	.1540	43	.0890	63	.0370
4	.2090	24	.1520	44	.0860	64	.0360
5	.2055	25	.1495	45	.0820	65	.0350
6	.2040	26	.1470	46	.0810	66	.0330
7	.2010	27	.1440	47	.0785	67	.0320
8	.1990	28	.1405	48	.0760	68	.0310
9	.1960	29	.1360	49	.0730	69	.0292
10	.1935	30	.1285	50	.0700	70	.0280
11	.1910	31	.1200	51	.0670	71	.0260
12	.1890	32	.1160	52	.0635	72	.0250
13	.1850	33	.1130	53	.0595	73	.0240
14	.1820	34	.1110	54	.0550	74	.0225
15	.1800	35	.1100	55	.0520	75	.0210
16	.1770	36	.1065	56	.0465	76	.0200
17	.1730	37	.1040	57	.0430	77	.0180
18	.1695	38	.1015	58	.0420	78	.0160
19	.1660	39	.0995	59	.0410	79	.0145
20	.1610	40	.0980	60	.0400	80	.0135

Decimal Equivalents of Millimeters

mm.	Inches	mm.	Inches	mm.	Inches	mm.	Inches	mm.	Inches
.01	.00039	.41	.01614	.81	.03189	21	.82677	61	2.40157
.02	.00079	.42	.01654	.82	.03228	22	.86614	62	2.44094
.03	.00118	.43	.01693	.83	.03268	23	.90551	63	2.48031
.04	.00157	.44	.01732	.84	.03307	24	.94488	64	2.51968
.05	.00197	.45	.01772	.85	.03346	25	.98425	65	2.55905
.06	.00236	.46	.01811	.86	.03386	26	1.02362	66	2.59842
.07	.00276	.47	.01850	.87	.03425	27	1.06299	67	2.63779
.08	.00315	.48	.01890	.88	.03465	28	1.10236	68	2.67716
.09	.00354	.49	.01929	.89	.03504	29	1.14173	69	2.71653
.10	.00394	.50	.01969	.90	.03543	30	1.18110	70	2.75590
.11	.00433	.51	.02008	.91	.03583	31	1.22047	71	2.79527
.12	.00472	.52	.02047	.92	.03622	32	1.25984	72	2.83464
.13	.00512	.53	.02087	.93	.03661	33	1.29921	73	2.87401
.14	.00551	.54	.02126	.94	.03701	34	1.33858	74	2.91338
.15	.00591	.55	.02165	.95	.03740	35	1.37795	75	2.95275
.16	.00630	.56	.02205	.96	.03780	36	1.41732	76	2.99212
.17	.00669	.57	.02244	.97	.03819	37	1.45669	77	3.03149
.18	.00709	.58	.02283	.98	.03858	38	1.49606	78	3.07086
.19	.00748	.59	.02323	.99	.03898	39	1.53543	79	3.11023
.20	.00787	.60	.02362	1.00	.03937	40	1.57480	80	3.14960
.21	.00827	.61	.02402	1	.03937	41	1.61417	81	3.18897
.22	.00866	.62	.02441	2	.07874	42	1.65354	82	3.22834
.23	.00906	.63	.02480	3	.11811	43	1.69291	83	3.26771
.24	.00945	.64	.02520	4	.15748	44	1.73228	84	3.30708
.25	.00984	.65	.02559	5	.19685	45	1.77165	85	3.34645
.26	.01024	.66	.02598	6	.23622	46	1.81102	86	3.38582
.27	.01063	.67	.02638	7	.27559	47	1.85039	87	3.42519
.28	.01102	.68	.02677	8	.31496	48	1.88976	88	3.46456
.29	.01142	.69	.02717	9	.35433	49	1.92913	89	3.50393
.30	.01181	.70	.02756	10	.39370	50	1.96850	90	3.54330
.31	.01220	.71	.02795	11	.43307	51	2.00787	91	3.58267
.32	.01260	.72	.02835	12	.47244	52	2.04724	92	3.62204
.33	.01299	.73	.02874	13	.51181	53	2.08661	93	3.66141
.34	.01339	.74	.02913	14	.55118	54	2.12598	94	3.70078
.35	.01378	.75	.02953	15	.59055	55	2.16535	95	3.74015
.36	.01417	.76	.02992	16	.62992	56	2.20472	96	3.77952
.37	.01457	.77	.03032	17	.66929	57	2.24409	97	3.81889
.38	.01496	.78	.03071	18	.70866	58	2.28346	98	3.85826
.39	.01535	.79	.03110	19	.74803	59	2.32283	99	3.89763
.40	.01575	.80	.03150	20	.78740	60	2.36220	100	3.93700

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